JAMES WEBB SPACE TELESCOPE: 12 SURPRISING DISCOVERIES

ALL ABOUT SPACE™

ISSUE 145
AUGUST 2023

BEYOND PLUTO

FROM PLANET X TO OBJECTS FROZEN IN TIME WHAT TRULY LURKS OUTSIDE THE SOLAR SYSTEM'S CHAOTIC FRONTIER

SHOULD WE COLONISE MARS?

WHAT IS CAUSING THE BIGGEST EXPLOSION IN SPACE?

INTERVIEW: WHEN A COMET HIT JUPITER

WHY THE UNIVERSE IS MAGNETIC

THE TWIN PARADOX

FUTURE
ISSUE 145

CELESTRON®

OVER 60 YEARS
OF INNOVATIVE TECHNOLOGY

REACH FOR THE STARS

The world's most beloved telescope! The classic, 8-inch Schmidt-Cassegrain revolutionised amateur astronomy in the 1970s. Now, the iconic "orange tube" design is updated with all the latest features to provide the best stargazing experience for beginners and experienced observers alike.

StarBright® XLT COATINGS

SkyAlign®
Revolutionary Alignment Technology

All-Star™ POLAR ALIGNMENT

★★★★½

"Legendary catadioptric telescope performance, view the stars and far-reaching deep sky objects"
SPACE.COM

NexStar® SE

Model shown: NexStar 8SE SCT
RRP £1699.99

Have any questions? Contact us:
Email: **enquiries@celestron.com**

@celestronuk
SCAN THE QR to discover more!

WELCOME

ISSUE 145

SCAN HERE TO GET OUR DAILY NEWSLETTER

Cast your mind back to 14 July 2015... that was the day NASA's New Horizons spacecraft gave us our first close-up look of Pluto and its moons. Heading beyond the dwarf planet, further into the outer Solar System, the spacecraft – travelling at a speed of at least 83,000 kilometres per hour (51,0000 miles per hour) – entered the Kuiper Belt, giving us a view of the dual-lobed trans-Neptunian object 486958 Arrokoth, and later, in 2018, confirmed the existence of a hydrogen wall at the edge of our solar neighbourhood. But what lies beyond the confines of our Solar System? In our cover feature this issue, we speak to the experts, who have given us their best guesses on what we're likely to find when we send more missions to explore beyond Pluto and the Kuiper Belt.

Enjoy the issue. I'll see you again on 10 August, where we delve into how artificial intelligence is changing astronomy and space exploration, explore our galaxy, learn about some amusing space pranks and so much more.

Wishing you clear skies!

GEMMA LAVENDER
Editor

42 Subscribe to All About Space today and you'll receive

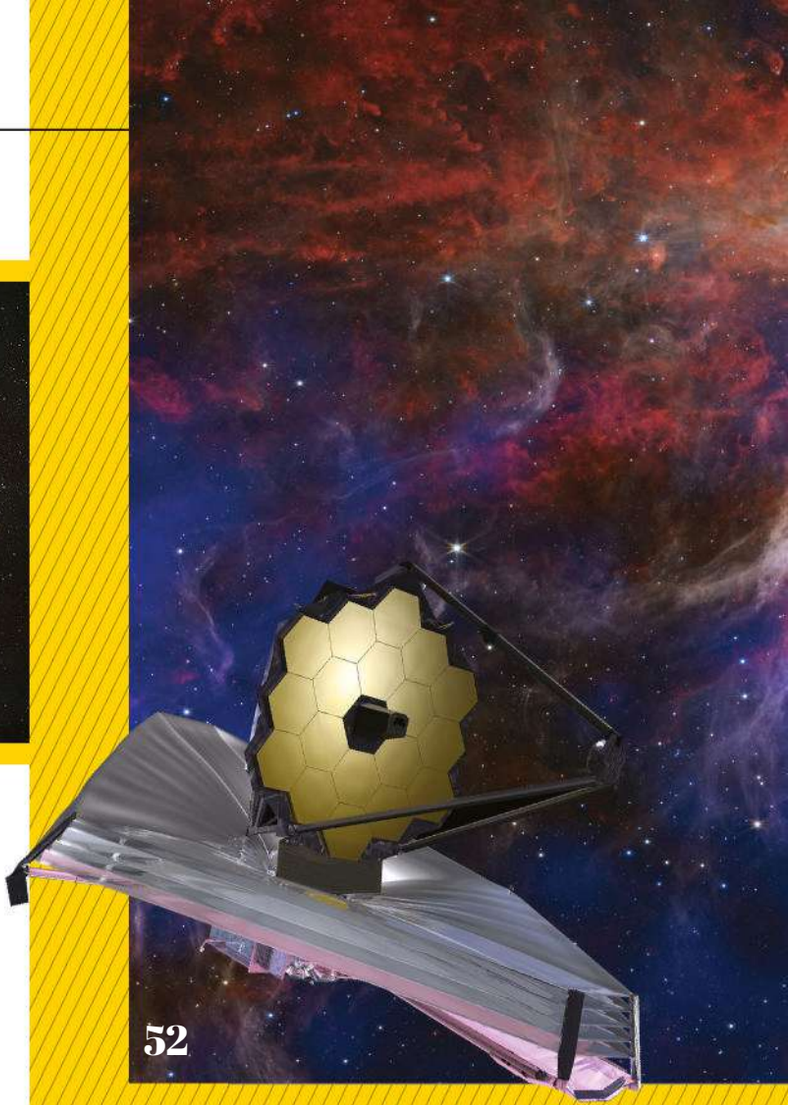
- ✔ **Great savings off the cover price**
- ✔ Every issue delivered straight to your door or digital device before it arrives in the shops
- ✔ **Exclusive subscriber-edition covers**

ALL ABOUT SPACE ISSUE 146

ON SALE 10 AUGUST

INSIDE

16 BEYOND PLUTO



52

LAUNCHPAD

06 News from around the universe

FOCUS ON

23 Webb has discovered a gargantuan geyser on Saturn's moon

FUTURE TECH

24 Manned mission to an asteroid

NASA plans to send manned expeditions to near-Earth asteroids

INTERVIEW

26 David Levy

Levy was immortalised for his co-discovery of Comet Shoemaker-Levy 9

FOCUS ON

30 China plans to put astronauts on the Moon before 2030

32 Can space exploration really be ethical?

Human exploration and exploitation of space continues to raise many ethical issues

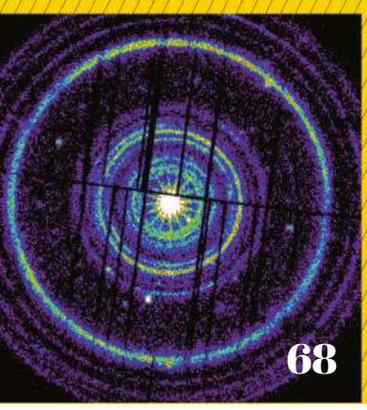
INSTANT EXPERT

40 Time dilation

What happens to time when travelling at extreme speeds?

44 The forgotten force

A seemingly weak magnetic entity could have made all the difference in our universe's evolution



68

FOCUS ON

50 A black hole shot out a bright X-ray jet 60,000 times hotter than the Sun

52 James Webb Space Telescope breakthroughs

New discoveries about planets, galaxies and other cosmic objects

FOCUS ON

60 Star system may hold the first evidence of an ultra-rare 'dark matter star'

62 What's the strangest thing sent into space?

Almost anything can make its way into the cosmos

FOCUS ON

66 Ice clouds high in Earth's atmosphere could help predict climate change

68 The largest cosmic explosion ever seen

Astronomers discovered a blast ten times brighter than any recorded before

FOCUS ON

74 NASA's Kepler space telescope discovered two mini-Neptunes before dying

76 Ask Space

Your questions answered by our panel of experts

26

STARGAZER

80 What's in the sky?

82 Planetarium

84 Month's planets

86 Moon tour

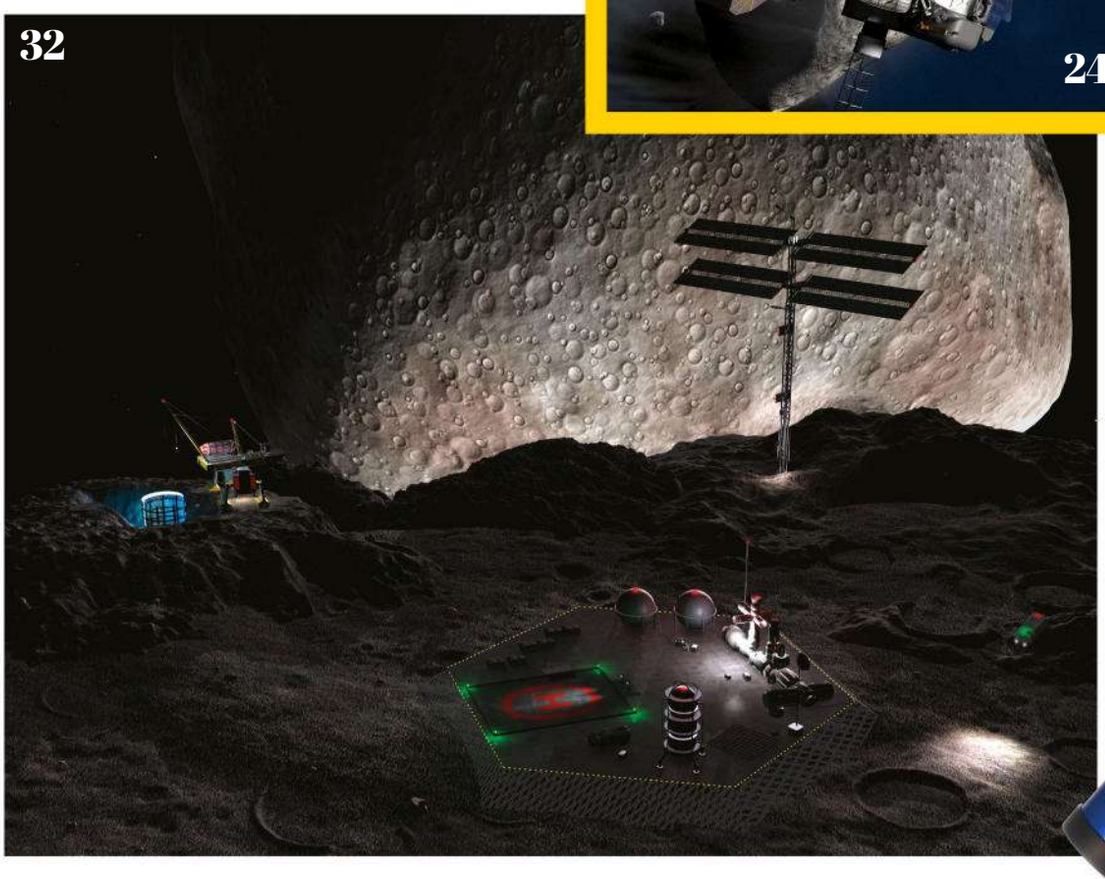
87 Naked eye & binocular targets

88 Deep sky challenge

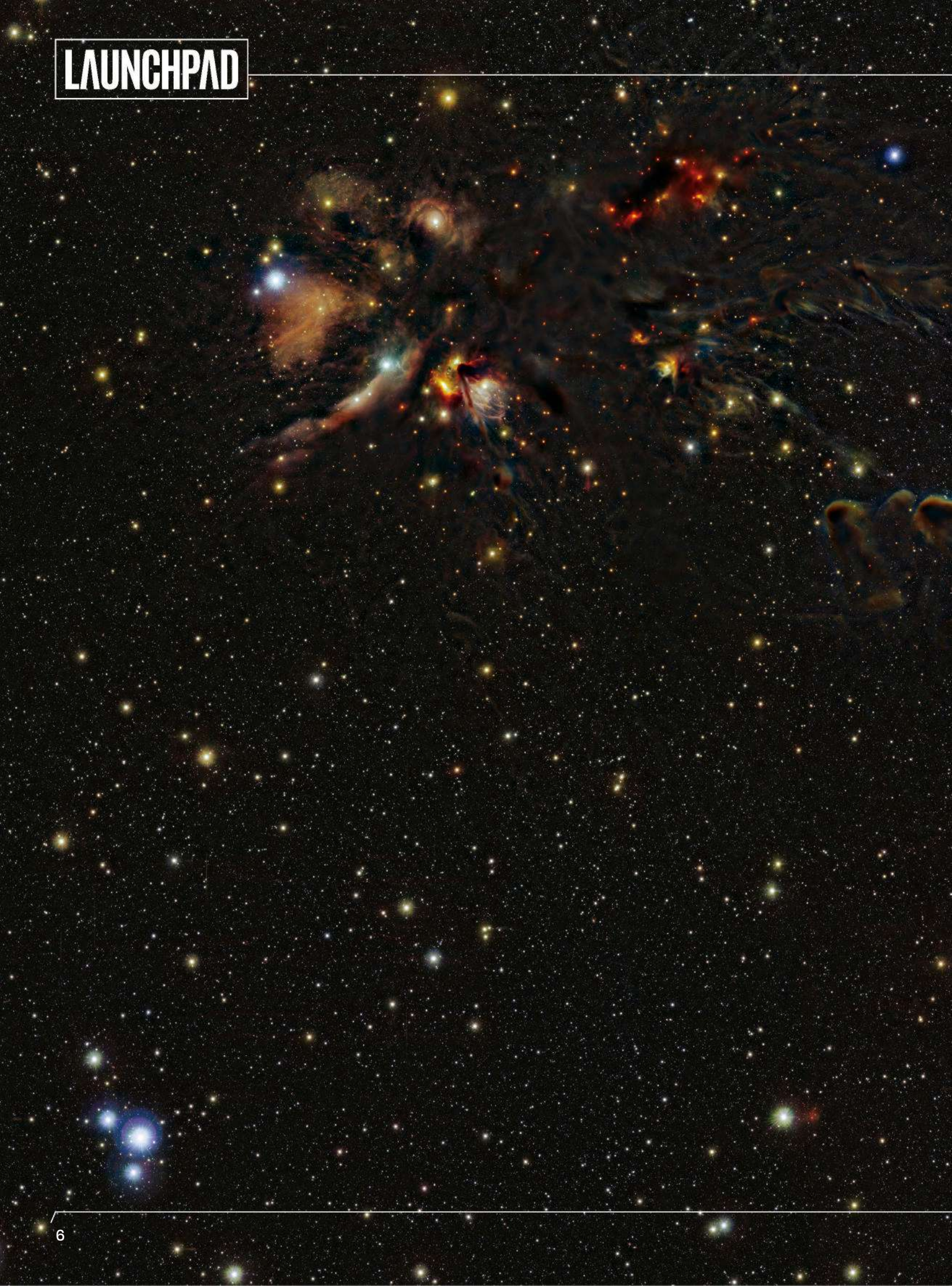
90 The Northern Hemisphere

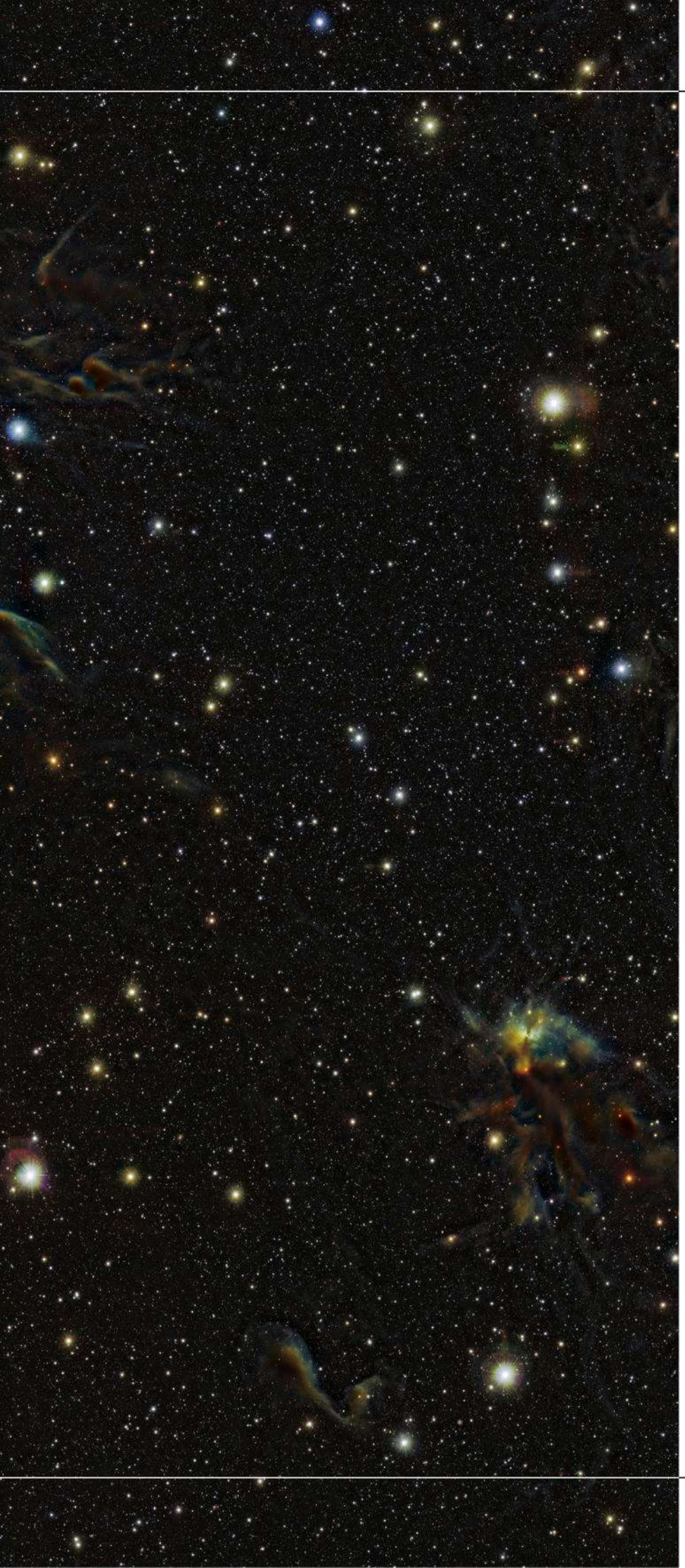
92 Review

96 In the shops



WIN!
MEADE POLARIS 130MD WORTH £250
15





11 May 2023

A million cosmic baby pictures form a vast star atlas

A fresh atlas of five nearby stellar nurseries shows infant stars shining through the dense clouds of gas and dust from which they were formed. The atlas brings to light vast star birthplaces in infrared light. Astronomers created it by stitching together over a million cosmic baby pictures using the Visible and Infrared Survey Telescope for Astronomy (VISTA) at the European Southern Observatory's (ESO) Paranal Observatory in Chile.

Astronomers know that stars form when cool and extremely dense patches in vast dust and gas clouds collapse under their own gravity. But details such as how many stars a dust cloud can birth – and how many of these stars will go on to host planets – are less clear.

The observations from VISTA could help astronomers better understand these aspects of star birth and the complex process that leads to early stellar evolution. "In these images, we can detect even the faintest sources of light, like stars far less massive than the Sun, revealing objects that no one has ever seen before," said research lead and University of Vienna astronomer Stefan Meingast. "This will allow us to understand the processes that transform gas and dust into stars."

Meingast and his colleagues studied the local star-forming regions of Orion, Ophiuchus, Chamaeleon, Corona Australis and Lupus with the VISTA infrared instrument VIRCAM, also known as the VISTA Infrared Camera. The proximity of the surveyed star-birthing regions and their immense size means they span a large area of the night sky. VIRCAM's huge field of view allows for detailed study, given it can see a sky area as wide as three full Moons.

VIRCAM allowed the astronomers to capture light from deep within the clouds of dust, which are all less than 1,500 light years away, and thus glimpse infant stars that had never been seen before. "The dust obscures these young stars from our view, making them virtually invisible to our eyes," team member and University of Vienna PhD student Alena Rottensteiner explained. "Only at infrared wavelengths can we look deep into these clouds, studying the stars in the making."

© NASA

23 May 2023

Webb teams up with Chandra

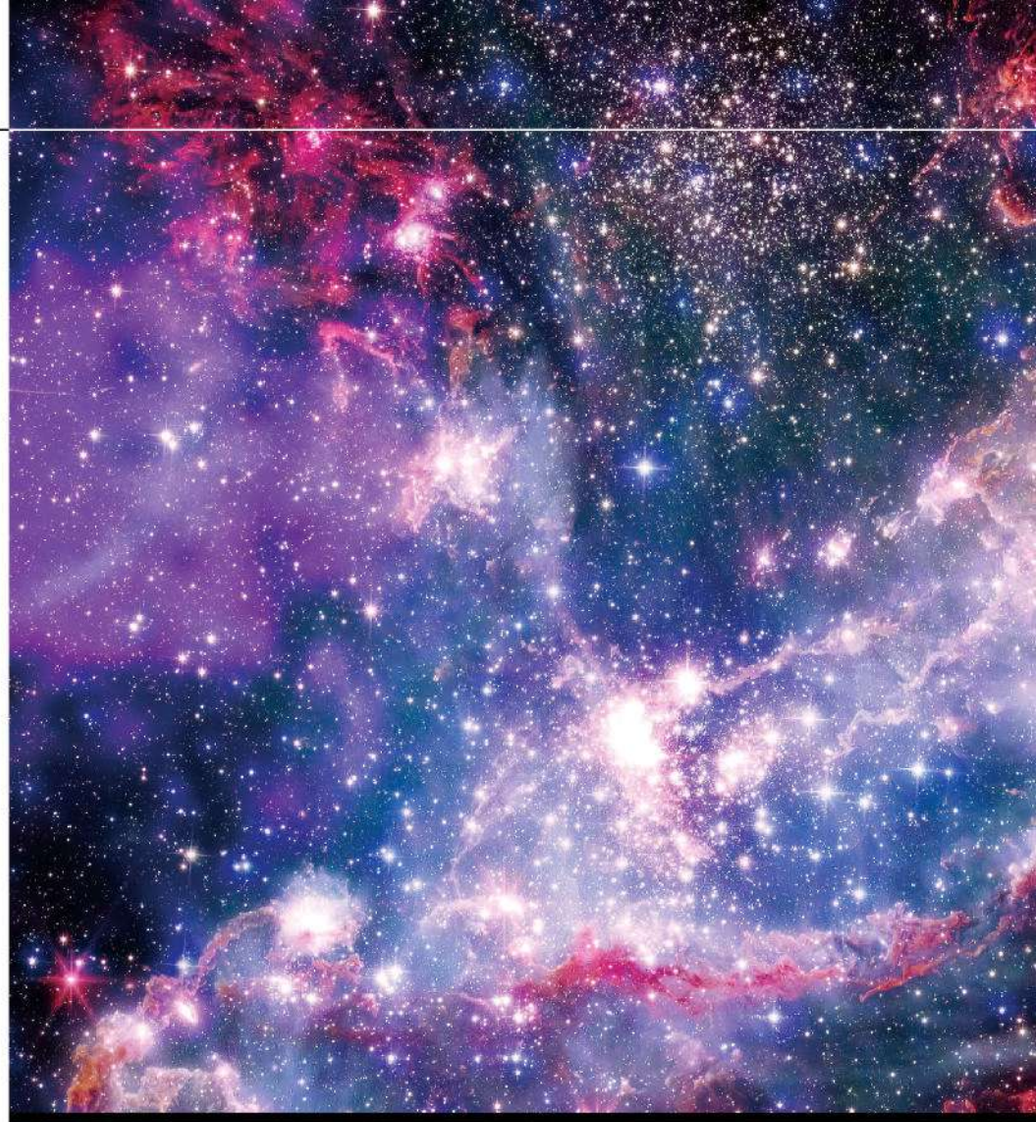
NASA has released four composite images using data from several of its most advanced telescopes to depict our universe in different wavelengths of light, including data collected by the Chandra X-Ray Observatory, the James Webb Space Telescope and the Hubble Space Telescope. The images, which show the Phantom Galaxy (Messier 74), NGC 1672, star cluster NGC 346 and the Eagle Nebula (Messier 16), are rendered in dazzling colours representing X-ray and infrared radiation, as well as optical light.

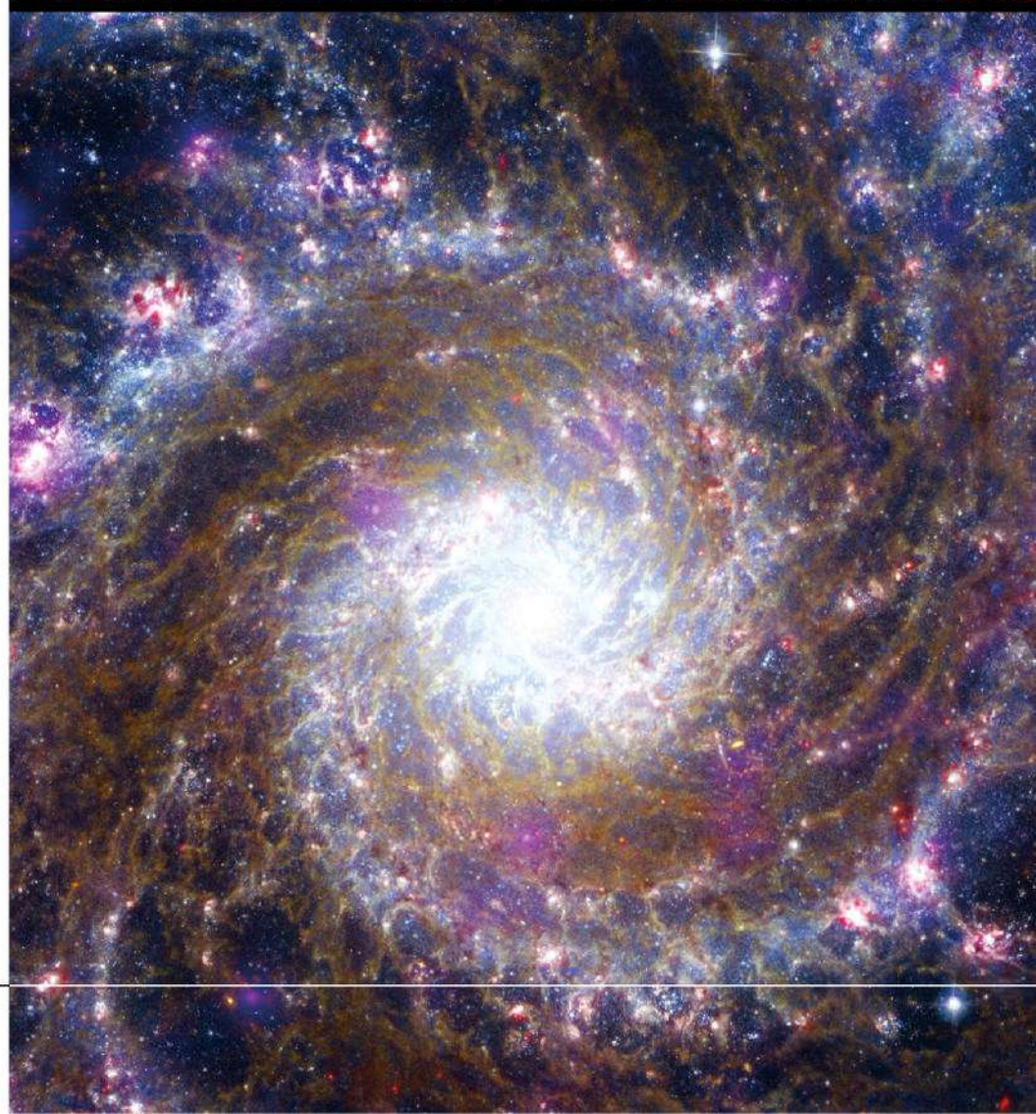
Categorised as a barred-spiral galaxy for its straight 'barred' arms of stars near its centre, NGC 1672 is a galaxy about 60 million light years from Earth. The new composite image shows several areas, especially in its outer arms, emitting intense X-ray radiation, shown in purple. These areas represent super-dense objects, such as neutron stars and black holes, that are pulling material into the galaxy.

Meanwhile, Messier 74 is a spiral galaxy like our own galactic home the Milky Way, located about 32 million light years away from us. It's called the Phantom Galaxy because it's visibly very dim. The galaxy has an intricate lacy structure, revealed by Webb. And data from Chandra notes multiple sources of X-ray radiation, including young stars, dotting the spiral.

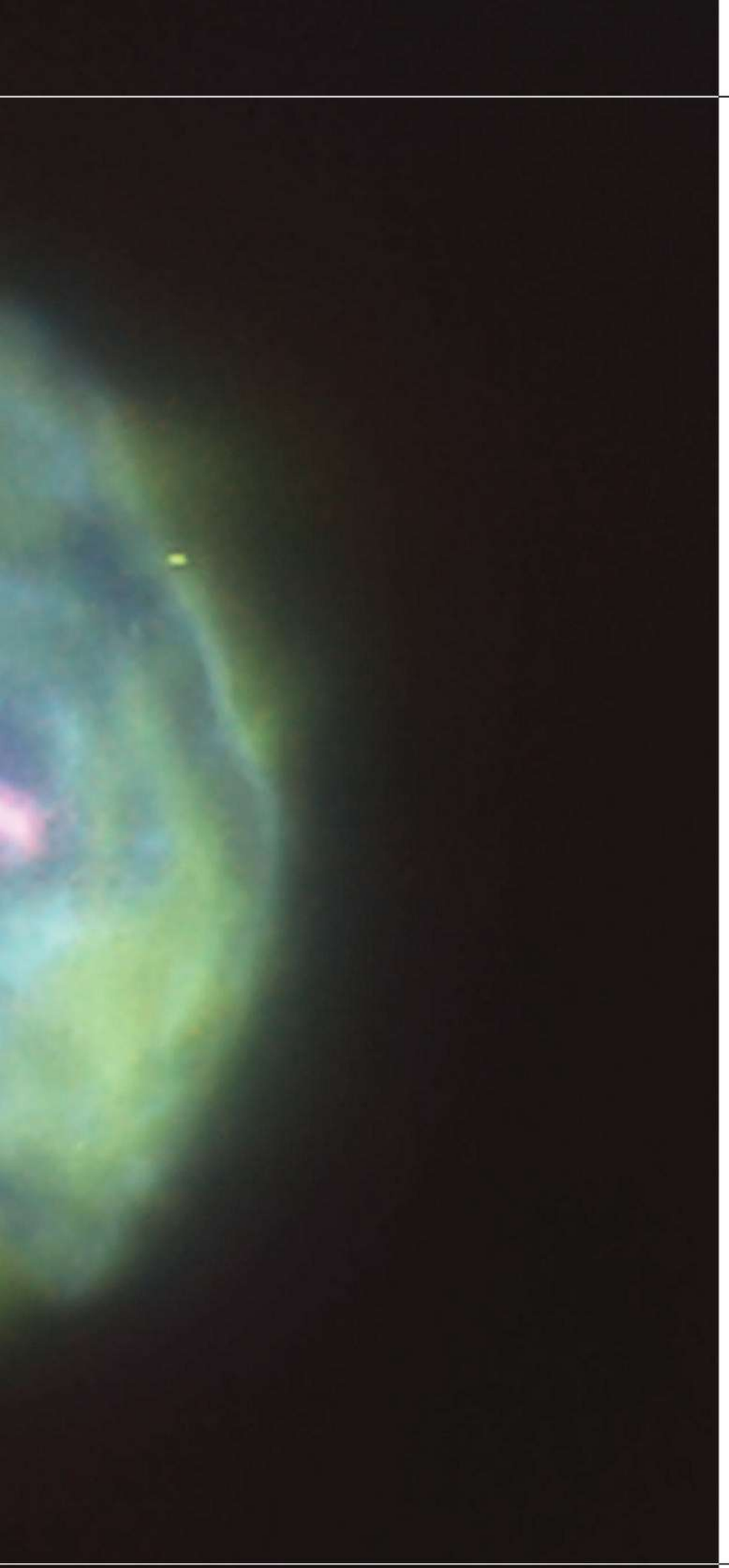
Messier 16 is about 6,500 light years away. The image shows the nebula's famous 'Pillars of Creation', dramatic clouds of dust and gas containing young stars, the most intense of which are highlighted in brilliant pinks and purples to show the powerful X-rays they emit. The image highlights the finding that most of these young, X-ray-emitting stars are actually outside the pillars, with only a few young stars emitting this intense radiation from within the clouds.

The image with the most notable contribution by Chandra might be of NGC 346, a star cluster in the Small Magellanic Cloud, a galaxy 200,000 light years from Earth. A bright-purple splotch on the left side of the image highlights the remnants of a supernova explosion, the spectacular death of a huge star. The NGC 346 cluster is also speckled with purple-white blotches of X-rays emitted from young, massive stars.





© NASA



17 April 2023

The Orion Nebula's stellar sprinkler

A new image captures a winding jet of material that looks like a garden sprinkler expelled by a young stellar object. The target, formally known as 244-440, resides in the Orion Nebula, a stellar nursery that lies about 1,350 light years from Earth. Taken using the Multi Unit Spectroscopic Explorer (MUSE) instrument on the ESO's Very Large Telescope (VLT) in northern Chile, the photo captures the striking 'S' shape of the jet of matter.

The curved nature of the jet suggests that it may be coming from one star orbiting another star. "Very young stars are often surrounded by discs of material falling towards the star. Some of this material can be expelled into powerful jets perpendicular to the disc," ESO officials said. "The S-shaped jet of 244-440 suggests that what lurks at the centre of this object isn't one, but two stars orbiting each other. This orbital motion periodically changes the orientation of the jet, similar to a water sprinkler." Another possible explanation is that the radiation from other stars in the Orion molecular cloud complex – an extremely active star-forming region – could alter the shape of the jet, creating the S-shaped stream of matter observed.

The MUSE instrument was used to map the distribution of iron, nitrogen and oxygen around the young star, which are the red, green and blue coloured gases captured in the photo. MUSE captures data at different wavelengths, or colours, simultaneously, allowing astronomers to map the composition of the gas and how it moves.

© ESO

New Tatooine-like exoplanet discovered orbiting twin suns

Reported by Charles Q. Choi

For decades, astronomers wondered if planets with twin Suns like Luke Skywalker's fictional home world of Tatooine were only science fiction. Now, scientists have discovered a new Tatooine-like system that's home to multiple worlds. Binary stars, or two stars orbiting each other, are very common – about half of the Sun-like stars in the Milky Way Galaxy are in binary systems. Up to now, astronomers had confirmed the detection of 14 circumbinary planets – ones that whirl around both stars of a binary system at once. "Circumbinary planets were originally thought not to exist, since the binary stars stir up the planet-forming discs, creating a harsh environment for planets to form," study lead author Matthew Standing, an astrophysicist at the Open University, said. "This all changed with the discovery of Kepler-16 b in 2011 by the Kepler space telescope. This discovery showed that it must be possible for these planets to form."

Until now, just one binary system was known to host multiple planets – Kepler-47, located about 5,000 light years away in the constellation of Cygnus, the Swan. This multi-planetary circumbinary system possesses a whopping three known worlds, Kepler-47 b, d and c. In the a study, astronomers investigated the binary system TOI-1338, located about 1,320 light years from Earth in the constellation of Pictor. In 2020, NASA's exoplanet-hunting Transiting Exoplanet Survey Satellite (TESS) discovered a circumbinary planet dubbed TOI-1338 b orbiting TOI-1338's pair of stars.

Using the European Southern Observatory and the Very Large Telescope, both located in the Atacama Desert in Chile, the scientists tried pinpointing the mass of TOI-1338 b. Despite their best efforts, they couldn't achieve that. Instead they discovered a second planet. "With only 15 of these circumbinary planets known out of the over 5,200 total exoplanets discovered so far, it is exhilarating to be a part of this emerging branch of exoplanet science," Standing said. "Our preliminary results show that circumbinary planets seem to exist as frequently as planets around single stars."

The newfound world is called BEBOP-1c after the name of the project that collected the data, BEBOP, which stands for Binaries Escorted By Orbiting Planets. BEBOP-1 is another name for the binary system TOI-1338. BEBOP-1c is a gas giant about 65 times the mass of Earth and about five times less than Jupiter's mass. It orbits its stars at a distance of about 79 per cent of an astronomical unit – one astronomical unit is the average distance between Earth and the Sun. And it takes about 215 days to complete a voyage around its suns. In comparison, TOI-1338 b is located about 46 per cent of an astronomical unit from its stars and takes about 95 days to orbit them. The scientists estimate it is at most 22 times Earth's mass.

Using the TESS space telescope, a high-school student helped discover TOI-1338 b when it passed, or 'transited', in front of the brighter of its two stars on several occasions. This helped the researchers estimate its size – about the same as Saturn – but not its mass. In contrast, in the new study the researchers were monitoring this binary system by looking for wobbles in the orbits of the stars. This 'radial velocity' method can detect the gravitational tug of planets. The gravity of a planet is related to its mass, so this wobbling can help reveal how much a planet weighs.

BEBOP-1c is the first circumbinary planet detected with the radial velocity technique alone, study co-author Amaury Triaud, an astrophysicist at the University of Birmingham, said. Its discovery would have come earlier – COVID-19 led to temporary closures of the observatories that helped detect BEBOP-1c, delaying these findings for a year.

Two planets have been found in orbit around a binary pair of stars

> "Preliminary results show that circumbinary planets seem to exist as frequently as planets around single stars"
>
> **Matthew Standing**

The progress of climate change has accelerated in recent years despite political pledges to curb greenhouse gas emissions

Earth is getting hotter at a faster rate despite pledges of government action

Reported by Tereza Pultarova

Average global temperatures are rising at an ever-faster rate despite pledges by world leaders to tackle climate change. A new study, released last week during a preparatory meeting for the 2023 United Nations Climate Change Conference that will take place later this year in the United Arab Emirates, found that the pace of global warming has accelerated in recent years despite political commitments to curb the progress of the temperature rise to 1.5 degrees Celsius (2.7 degrees Fahrenheit) compared to preindustrial times.

Global temperatures increased on average by 1.07 degrees Celsius (1.93 degrees Fahrenheit) in the decade from 2010 to 2019, but the average rise in the decade from 2013 to 2022 was 1.14 degrees Celsius (2.05 degrees Fahrenheit). That means that the pace of human-induced climate change is accelerating at a rate of over 0.2 degrees Celsius per decade. The researchers said that the still-rising levels of human-made greenhouse gas emissions are the main culprit.

In 2015, at the United Nations Climate Change Conference in Paris, leaders from 195 nations agreed to work towards limiting global warming to 1.5 degrees Celsius (2.7 degrees Fahrenheit) compared to preindustrial times. Despite this agreement, emissions of key greenhouse gases are "at an all-time high," the study found. In the last decade, humankind has been releasing about 54 gigatonnes of carbon dioxide every year into Earth's atmosphere through various industrial activities. The failure to curb these emissions means that humankind can now only release about 250 more gigatonnes of carbon dioxide before global warming reaches the limit. In a previous carbon budget assessment in 2020, researchers found that humankind still had over 500 gigatonnes of carbon dioxide left to reach the threshold, showing that without significant changes, the world will be through its global carbon budget in less than five years.

"Even though we are not yet at 1.5 degrees Celsius [2.7 degrees Fahrenheit] warming, the carbon budget will likely be exhausted in only a few years, as we have a triple whammy of heating from very high carbon dioxide emissions, heating from increases in other greenhouse gas emissions and heating from reductions in pollution," Piers Forster, director of the Priestley Centre for Climate Futures at Leeds University and one of the authors of the study, said. "If we don't want to see the goal disappearing in our rear-view mirror, the world must work much harder and urgently at bringing emissions down."

HOW IT WORKS
subscription offer
FROM £2.50 PER ISSUE!
PRINT

DIGITAL

PRINT & DIGITAL

This offer is **only** available via our online shop
www.magazinesdirect.com

© Getty

A new Pentagon-funded hypersonic test vehicle could fly in summer 2024

Reported by Andrew Jones

A new experimental hypersonic cruise vehicle could be flying as soon as next summer under an initiative from the US Defense Innovation Unit (DIU). The DART AE high-speed test aircraft is being developed by Hypersonix Launch Systems following the award of a prototype contract. DART AE is a 300-kilogram scramjet-powered technology demonstrator that can reach speeds of up to Mach 7.

The DIU, which operates under the US Department of Defense (DoD), describes itself as an organisation focused on accelerating the adoption of commercial and dual-use technology to solve operational challenges at speed and scale. The Pentagon is pursuing research and development of hypersonic defence programs. As part of this, the DIU has rolled out the high-cadence testing capabilities (HyCAT) project, which brings opportunities for commercial companies to develop reusable and low-cost test vehicles and reduce strain on DoD resources. Lieutenant colonel Nicholas Estep, HyCAT program manager, revealed that the DIU is refining the details of the mission, including the flight conditions, the launch provider and the location for next year's first fully integrated autonomous flight of DART AE.

Fenix Space, located in San Bernardino, California, and Rocket Lab, located in Long Beach, California, have also been awarded DIU contracts for a reusable tow-launch platform and the Hypersonic Accelerator Suborbital Test Electron (HASTE) rocket, respectively.

Scientists beam solar power to Earth from space for the first time

Reported by Robert Lea

A space solar power prototype has demonstrated its ability to wirelessly beam power through space and direct a detectable amount of energy towards Earth for the first time. The experiment proves the viability of tapping into a near-limitless supply of power in the form of energy from the Sun from space. Because solar energy in space isn't subject to factors like day and night, obscuration by clouds or weather on Earth, it's always available. In fact, it's estimated that space-based harvesters could potentially yield eight times more power than solar panels at any location on the surface of the globe. The wireless power transfer was achieved by the Microwave Array for Power-transfer Low-orbit Experiment (MAPLE), an array of flexible and lightweight microwave power transmitters, which is one of the three instruments carried by the Space Solar Power Demonstrator (SSPD-1).

SSPD-1 was launched in January 2023 as part of the California Institute of Technology's Space Solar Power Project (SSPP), the primary goal of which is to harvest solar power in space and then transmit it to the surface of Earth. MAPLE demonstrated the transmission of energy wirelessly through space by sending energy from a transmitter to two separate receiver arrays around 30 centimetres (one foot) away, where it was transformed into electricity. This was used to light up a pair of LEDs. The instrument then beamed energy from a tiny window installed in the unit to the roof of the Gordon and Betty Moore Laboratory of Engineering on the California Institute of Technology's campus in Pasadena.

Because MAPLE isn't sealed, the experiment also demonstrated its capability to function in the harsh environment of space while subject to large swings in temperature and exposure to solar radiation. The conditions experienced by this prototype will soon be felt by large-scale SSPP units.

Artist's illustration of a hypersonic cruise missile

An image of the interior of MAPLE, the instrument aboard the Space Solar Power Demonstrator that achieved the wireless transmission of energy through space

© U.S. Air Force; SSPP

WIN

MEADE POLARIS 130MD WORTH £250!

Kick-start your stargazing hobby with this month's competition prize

With its five-inch aperture, the Meade Polaris 130MD delivers exquisite views of a wide selection of night sky objects – from Solar System targets to bright deep-sky objects such as the Andromeda Galaxy and the Orion Nebula. A stable German equatorial mount with slow controls enables easy tracking, allowing you to keep objects in your field of view as they move across the night sky, while a motor drive allows multi-speed tracking of the Moon, planets and stars. A stainless-steel tripod with an accessory tray to hold the supplied 6.3mm, 9mm and 26mm three-element eyepieces and a 2x Barlow Lens provides the finishing touch to a sturdy and capable instrument.

A breeze to set up, this reflector offers good portability, offering you the versatility of transporting it the short distance to your back garden or further afield to your favourite dark-sky location. The supplied Autostar Suite planetarium software contains information on over 10,000 objects to ensure that you're free to tour the night sky, whatever the weather!

To be in with a chance of winning, answer this question:

What's the most common type of star in the universe?

A: Blue supergiant

B: Red dwarf

C: Neutron star

Competition ends on 10 August 2023

Enter via email at **space@spaceanswers.com**
Visit the website for full terms and conditions at **futureplc.com/terms-conditions**

BEYOND PLUTO

From Planet X to objects frozen in time – what truly lurks outside the Solar System's chaotic frontier

Reported by James Romero

"Like an archaeological dig into the history of our Solar System." That's how New Horizons principal investigator Howard Stern described the spacecraft's mission to Pluto and the outer Solar System. In recent decades, our ability to peer into the murky edges of the Solar System and map the populations of icy bodies that reside there has not only changed our understanding of the true scale and nature of the Solar System, but has also shone a light on the past, on how the current arrangement of rocky and icy worlds came to be and how interactions with the wider galaxy might shape its future.

Residents of the outer Solar System can be divided into various populations by their current orbits, history of orbital interactions or their compositional make-up. Kuiper Belt objects (KBOs) are the first population encountered as you move beyond the orbit of Neptune at around 30 astronomical units (AU) – one AU is the Earth-Sun distance. This sparsely populated ring extends out to 2,000 AU and includes icy bodies left over from the formation of the Solar System. Larger residents include Pluto, as well as Eris, Makemake and Haumea, which along with many much smaller inhabitants form a large subgroup known as 'hot' Kuiper belt objects.

Hot KBOs owe their current positions to an ancient eviction of between 10 and 30 Earth masses worth of small bodies from the Solar System's inner regions, likely caused by ancient jostling of young gas and ice giants. This violent event is still evident

"Outside of the Kuiper Belt and hypothetical Oort Cloud, there's a population of bodies fitting neither category"

WORLDS BEYOND PLUTO

Haumea
Haumea's combination of rings and moons is yet to be explained by astronomers.

Farfarout
In 2021 Farfarout was confirmed to be the most distant object ever observed in our Solar System.

Eris
Initially thought to be larger than Pluto, Eris' discovery helped end Pluto's planetary status.

Arrokoth
Arrokoth is the most distant object ever explored by a spacecraft.

Makemake
Its reddish hue is due to its surface composition of methane, ethane and possibly nitrogen ices.

© NASA; ESA; ESO; NOIRLab; Getty

in hot KBOs' eccentric orbits, often at significant angles from the general plane of the Solar System.

One significant source of insight on the Kuiper Belt, and Pluto in particular, has been the New Horizons mission. After leaving the former planet, the mission team utilised artificial intelligence, in collaboration with data from the Subaru Telescope, to search for the next object to target. The result was a trip to 486958 Arrokoth, a so-called cold KBO. Unlike Pluto and the hot KBO community, Arrokoth is a born and bred Kuiper Belter, forming pretty much in its current location early on in the Solar System's life.

Unlike the geologically active Pluto, with its terrain resurfaced by icy lava, 35-kilometre (21.7-mile) long Arrokoth represents the most primitive body ever observed up close. Its unique peanut shape results from the coming together of two planetesimals, the building blocks of planets, which formed everywhere throughout the early Solar System, but were stunted in their growth in the sparsely populated outer regions. These two lobes, delicately connected by a remarkably narrow neck, provide visual evidence of the stability and undisturbed experience of these ancient relics. And it's this pristine preservation that makes Arrokoth a potential reservoir of information about planetary formation in the early Solar System. "Arrokoth has lived its whole life about where it formed, with minimal impacts or other things happening to it," says Kelsi Singer, deputy project scientist on the mission. "That's why flying by Arrokoth was so revolutionary, because we got to see back in time to how planetesimals formed."

> **"Flying by Arrokoth was so revolutionary, because we got to see back in time to how planetesimals formed"**
> **Kelsi Singer**

One intriguing aspect of Arrokoth observed by New Horizons is the lack of violent fractures, which you might expect to see if these two lobes once smashed into one another. This suggests that gentle coalescence might be a more potent mechanism for planetary formation. With the exception of Arrokoth and the belt's larger residents, much of the remaining Kuiper Belt population are little more than points of light to astronomers, identified and tracked from Earth by space-based telescopes like Spitzer and a collection of Earth-based observation

- Pluto is the largest and most massive member of the Kuiper Belt
- Jupiter's trojan asteroids are thought to be the inner Solar System cousins of scattered Kuiper Belt objects
- There's evidence that Saturn's moon Phoebe may be a captured centaur from the outer Solar System

© Johns Hopkins APL

MAPPING THE OUTER SOLAR SYSTEM

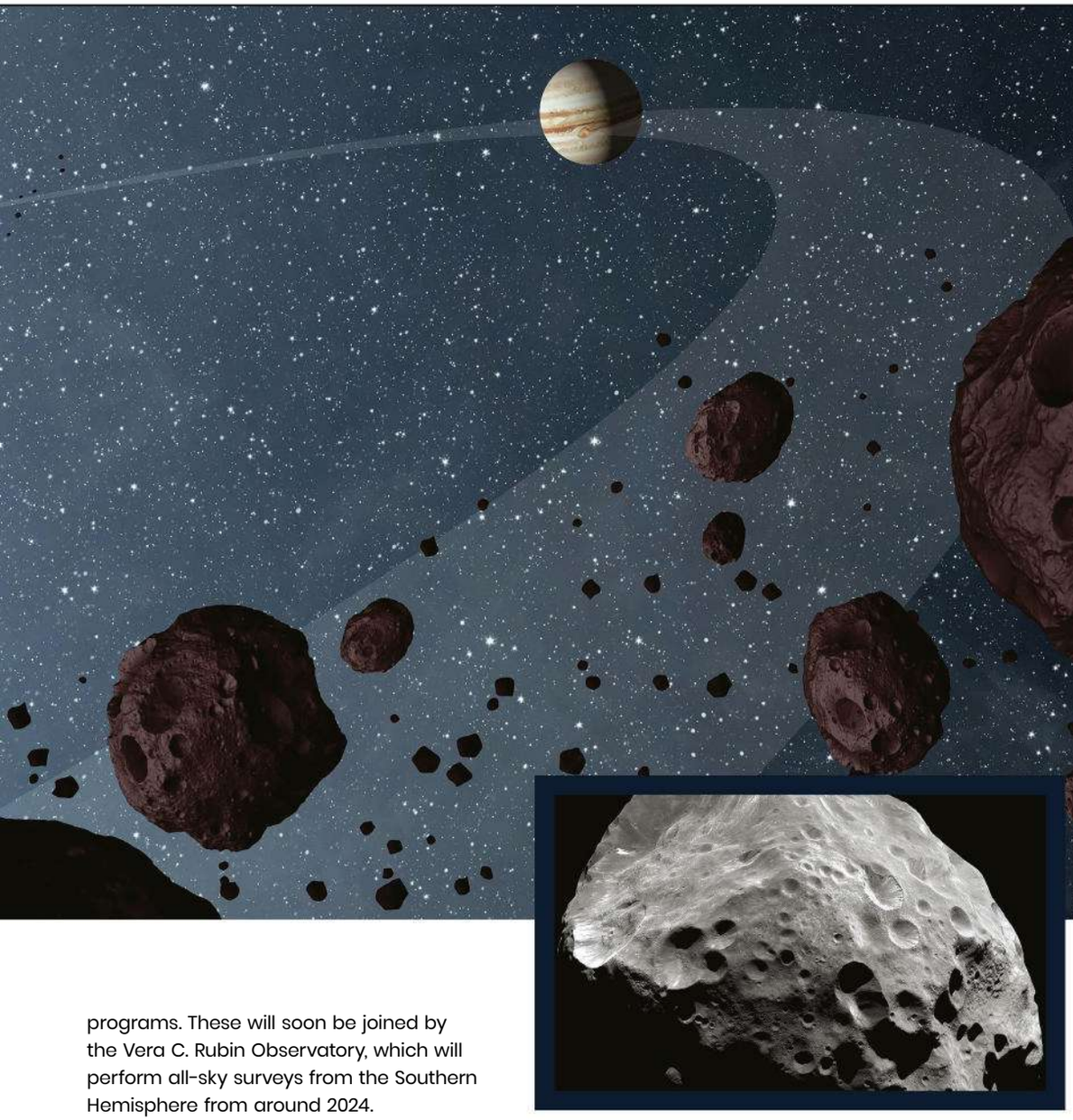
Heliosphere
0 to 122 AU
The outermost section of our Sun's atmosphere is a vast, bubble-like region of space that extends outwards.

Kuiper Belt
30 to 1,000 AU
A doughnut-shaped ring of icy objects orbiting around the Sun beyond Neptune's path.

Heliopause
123 AU
A theoretical boundary where the Sun's solar wind is stopped by the interstellar medium.

Interstellar space
From 123 AU
From here on, the Sun's constant flow of material and magnetic field have little to no effect on distant icy bodies.

Oort Cloud
2,000 to 100,000 AU
The most distant region in our Solar System, its residents are beyond the scope of current observatories.



programs. These will soon be joined by the Vera C. Rubin Observatory, which will perform all-sky surveys from the Southern Hemisphere from around 2024.

However, even this powerful new observatory won't shed much light on the next region on our trip outwards through the Solar System. As we approach a distance 3,000 times further from the Sun than Earth, we enter the mysterious Oort Cloud - the largest, if ultimately theoretical, region of the Solar System. The inner edge of this three-dimensional shell of icy debris is projected to be reached by the Voyager 1 spacecraft in roughly 300 years, while its outer limits could extend a light year in all directions. Within this diffuse, spherical bubble that encapsulates the Kuiper Belt, our Sun and all the inner planets are perhaps 100 billion icy planetesimals.

Too far out and faint to be observed from Earth, our understanding of the Oort Cloud is inferred from its residents that break free and head inwards. These long-period comets include Hale–Bopp, which lit up Earth's skies in the 1990s. Estonian philosopher and astronomer Ernst Öpik was the first to theorise that long-period comets might come from an area at the edge of our Solar System. Dutch astronomer Jan Oort predicted the existence of this cloud of icy bodies in the 1950s, describing a reserve of frosty objects that occasionally get kicked out of their orbits, probably due to gravitational interactions with other Oort Cloud bodies, and end up visiting the inner Solar System.

Other sources of gravitational influence that could turn Oort Cloud residents into long-period comets might come from outside our Solar System. Like the outer regions of the Kuiper Belt, the Oort Cloud is thought to be a region much more in touch with the wider galaxy than the inner Solar System, says Kat Volk, a senior scientist at the Planetary Science Institute. "The changing gravitational potential of the galaxy as the Sun is going around in the Milky Way can change their orbits because they're so weakly bound to the Sun."

In terms of what makes up the Oort Cloud, different simulations of the formation of our Solar System predict different origins. Some astronomers have suggested most residents are broadly similar to the hot Kuiper Belt

OUR EYES ON THE OUTER SOLAR SYSTEM

Subaru Telescope

Active: 1999 to present

Location: Hawaii

This 8.2-metre (26.9-foot) telescope is well suited for deep wide-field sky surveys and is the primary tool for looking for Planet Nine.

New Horizons

Active: 2015 to present

Location: 55 AU from Earth in the Kuiper Belt

The first spacecraft to explore Pluto up close, it has since also visited a second Kuiper Belt object, Arrokoth.

Spitzer Space Telescope

Active: 2003 to 2020

Location: Decommissioned in an Earth-trailing orbit

Spitzer's scientific forte was 'the old, cold and dusty', and it observed many Kuiper Belt objects, centaurs and comets.

Vera C. Rubin Observatory

Active: First light expected in 2024

Location: Chile

The new observatory aims to increase the number of catalogued Kuiper Belt objects and also help with the search for the hypothesised Planet Nine.

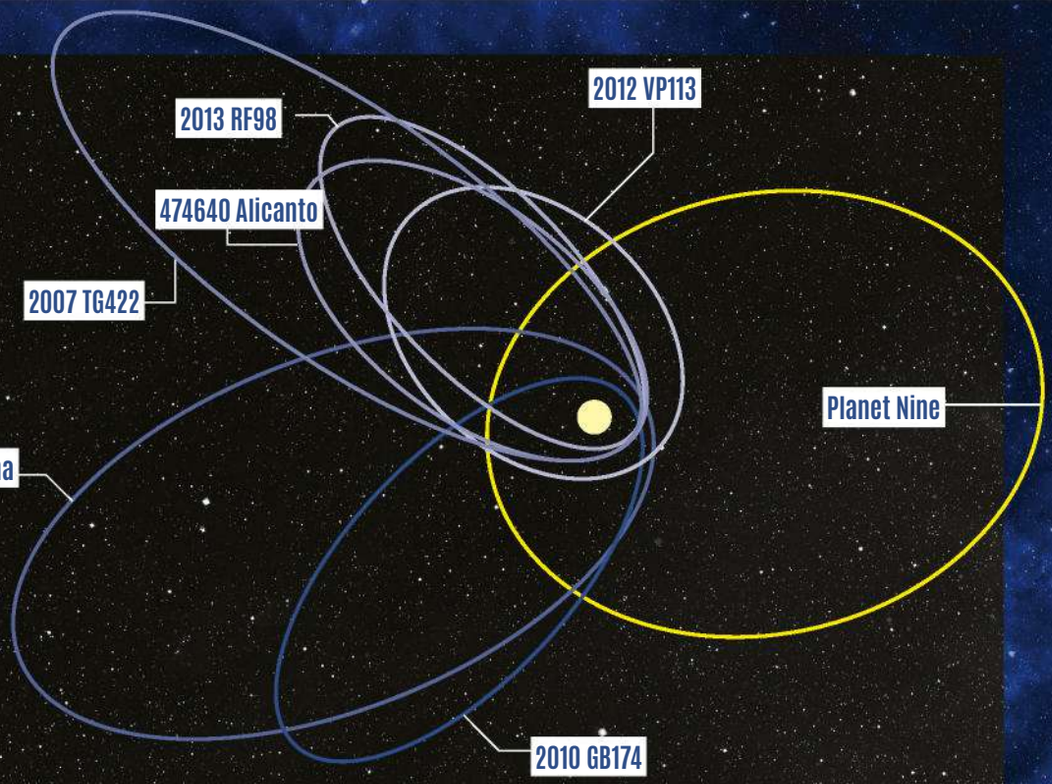
James Webb Space Telescope

Active: 2022 to present

Location: Earth-Sun Lagrange point L2

Astronomers are hoping to use Webb to get information about the surface chemistry of different populations in the Kuiper Belt.

© NASA; NAOJ; Rubin Observatory;



PLANET NINE'S ORBITAL PATH

How we think this world dances around the Sun

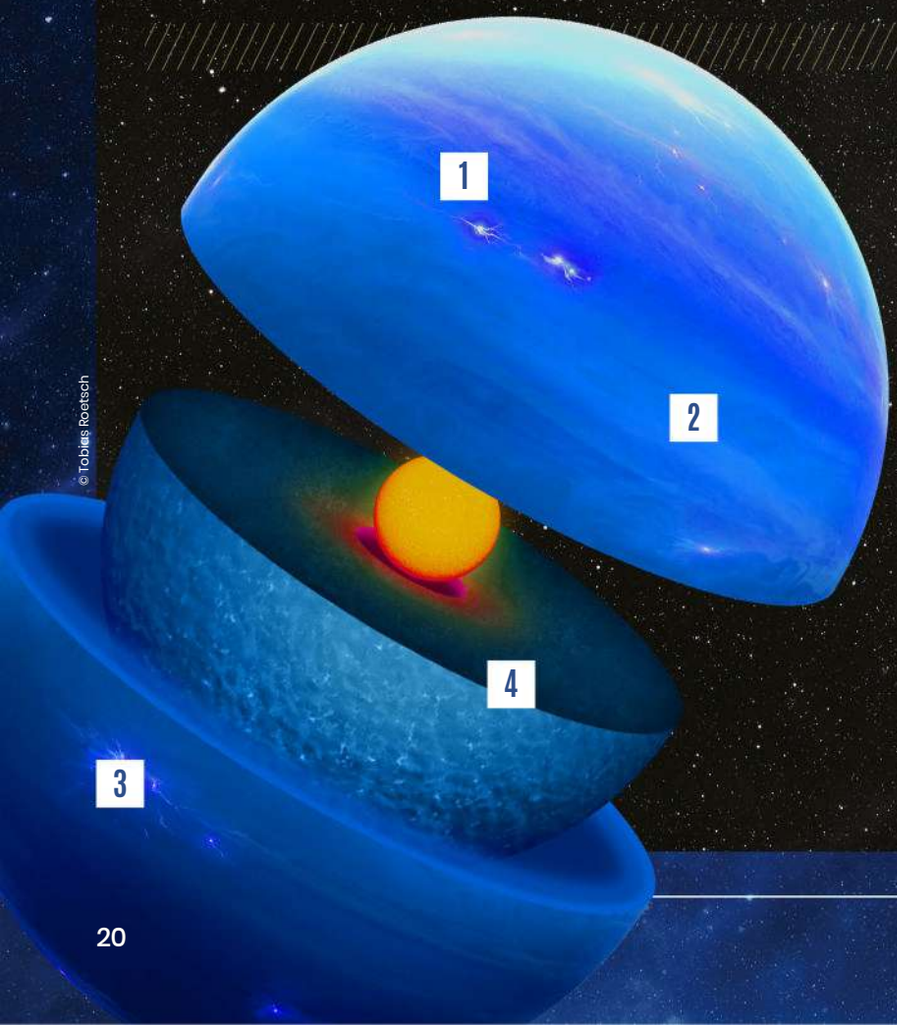
The next nearest planet
Neptune's orbit only takes it out to about 30 AU, more than six times less than the perihelion of Planet Nine.

The inclination
Compared to the other planets of the Solar System, Planet Nine is thought to be inclined by about 30 degrees.

The shape of its orbit
Planet Nine is thought to have a highly eccentric orbit, completing one revolution around the Sun in about 20,000 years.

Closest point
At its closest point to the Sun, known as perihelion, Planet Nine is predicted to approach about 200 AU.

Farthest point
Planet Nine's orbit is thought to extend out to a distance of up to 1,200 AU from the Sun into the far outer Solar System.



© Tobias Roetsch

WHAT COULD THIS OTHER WORLD BE MADE OF?

Here's what we know about the potential ninth planet

1 Its mass
The planet is thought to have a mass of between 5 and 15 Earths, which could make it a super-Earth type planet.

2 Cold as ice
Being located beyond the orbit of Neptune, it's likely to be extremely cold – any water the planet has will be frozen as ice.

3 On the surface
If the planet is smaller than 1.6 Earth radii it might have a rocky surface. If it's larger, it could be more similar to a gas giant.

4 Inside the planet
As we don't know the planet's radius, we can't yet tell what its core, mantle or atmosphere – if it has one – look like.

community – objects expelled by the giant inner planets during their formation. But others, like the Southwest Research Institute's Hal Levison, believe a significant proportion of the Oort Cloud population might have been captured from the backyards of a thousand or so star systems that were much closer to us when our Sun was born.

Outside of the Kuiper Belt and hypothetical Oort Cloud, there's a population of bodies fitting neither category. Centaurs are a collection of small bodies whose orbits, at their closest approach to the Sun, position them between Jupiter and Neptune. However, they then swing out beyond Pluto and well into the heart of the Kuiper Belt. In 2019, the most distant object ever discovered in the Solar System turned out to be a centaur. The appropriately nicknamed Farfarout was discovered by Scott Sheppard of the Carnegie Institution for Science and Chad Trujillo of Northern Arizona University using Subaru Telescope data. This distant world orbits the Sun every millennium at a maximum distance of 19.8 billion kilometres (12.3 billion miles). Despite its notoriety, Farfarout wasn't the ultimate aim of Sheppard and Trujillo's outer Solar System surveying. The object they were gathering evidence on was something far larger that had first been predicted a few years before.

In 2016, Mike Brown and Konstantin Batygin, both of the California Institute of Technology, announced evidence that the outer Solar System contained an undiscovered large body, which they dubbed 'Planet Nine'. Brown and Batygin used perceived asymmetry in the orbital alignment of extreme outer Solar System bodies as evidence of the gravitational influence of an unobserved world with a mass 6.2 times Earth's, orbiting between 300 and 380 AU. Brown and Batygin's idea wasn't completely out there. The 'Five-planet Nice model' of the early Solar System, proposed in 2011 by the Southwest Research Institute's David Nesvorný, explains the current locations of the gas and ice giants through the ejection of a fifth giant planet. However, data from the Wide-field Infrared Survey Explorer (WISE) has shown there's nothing Saturn-sized or bigger within a couple thousand AU of the Sun, as the infrared survey would have picked up the remaining planetary heat.

Volk, who proposed an ejected tenth planet of her own a few years later based on perceived torquing of the average orbital planes of some outer Solar System bodies, believes the evidence for both these hypothetical worlds has gotten weaker in recent years. This comes as the work of Sheppard, Trujillo and others has added

One of the most watched comets in history, Hale-Bopp originated in the Oort Cloud

© Getty

DEBATE: IS IT LIKELY THAT ANOTHER PLANET EXISTS?

Scientists are conflicted about the existence of a ninth Solar System planet

YES

If another world isn't there you need other theories to explain each of the anomalous patterns we see. You need a theory to explain why the orbits are aligned together, a theory to explain why objects are out of reach of Neptune and another to explain why some orbits get flipped upside down. Another planet explains all of these anomalies consistently.

Konstantin Batygin, California Institute of Technology

NO

One hypothesis involves the collective gravity of minor planets. These orbit so far away from the Sun that the weak gravity can build up slowly over time and come to dominate their dynamical evolution. They can rearrange their own orbits into a distribution similar to what we observe in the outer Solar System. This predicts there's a disc of minor planets more massive than the Kuiper Belt awaiting discovery.

Ann-Marie Madigan, University of Colorado, Boulder

> "Every time we get a big advancement in observational capabilities, we tend to find a population we didn't know was there before"
>
> **Kat Volk**

more objects and more data points to these orbital plots. Now she is looking to the upcoming Vera C. Rubin Observatory for final confirmation either way. "It might not detect any extra planets, but it will detect so many trans-Neptunian objects that we will put this asymmetry to bed… or not. It will either be confirmed, or there will be enough data to say no."

Despite casting doubt on Planet Nine and her own proposed tenth world, Volk thinks we will find something someday. However, given only 30 Earth masses of material is believed to have been ejected during the early Solar System reorganisation and the less-than-certain chance of anything ejected being gravitationally retained further out, her money is on something more Mars-sized. "I would be surprised, frankly, if we don't find something pretty decently large in the end."

As New Horizons enters its final few years in the Kuiper Belt, and with no new viable targets in its reticle, NASA has discussed repurposing the spacecraft to measure space weather and interstellar emissions. For outer Solar System population studies, this marks a return to Earth and near orbit-based searches, where new analytical techniques and machine learning could keep with adding plots to our orbital maps. However, understanding these dots of light as tiny worlds, rather than simply plots on a population graph, is going to require voyages beyond Pluto once again. "There's orders of magnitude more information that you could get about these bodies by visiting them at close range with a spacecraft mission," says Singer. "Obviously a spacecraft would be awesome," agrees Volk. "But realistically that's not going to happen any time soon, as there's really no funding in the latest NASA mission portfolio."

Fortunately, the outer Solar System's tendency to throw dirty snowballs inwards means the journey time to a flyby of an outer Solar System world can be cut down significantly. This was seen with the European Space Agency's Rosetta mission. In 2029 the Comet Interceptor will launch, setting up shop 1.5 million kilometres (93 million miles) from Earth. From there the craft will wait for a cometary visitor from the Oort Cloud to arrive, triggering a flyby manoeuvre. It's these ongoing opportunities for close-up observations of outer Solar System bodies, combined with enhanced Earth-based observation capabilities, which should ensure the exploration of the outer Solar System continues, says Volk - even as New Horizon's days of icy world flybys come to an end. "Every time we get a big advancement in observational capabilities, we tend to find a population we didn't know was there before."

James Romero
Science writer
James has written for *The Biologist*, *Physics World* and *BBC Science Focus*, among other publications. He specialises in planets, moons and astronomy.

Artist's impression of New Horizons encountering Kuiper Belt object Arrokoth

© NASA

FOCUS ON

JAMES WEBB SPACE TELESCOPE FINDS A GARGANTUAN GEYSER ON SATURN'S MOON

Scientists are longing to go back to the moon to sample the plume material for signs of life

Reported by Isobel Whitcomb

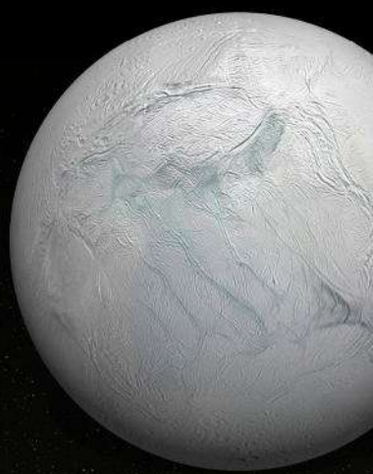
Scientists caught Saturn's icy moon Enceladus spraying a huge plume of watery vapour far into space – and that plume likely contains many of the chemical ingredients for life. "It's immense," Sara Faggi, a planetary astronomer at NASA's Goddard Space Flight Center, said. This isn't the first time scientists have seen Enceladus spout water, but the new telescope's wider perspective and higher sensitivity showed that the jets of vapour shoot much farther into space than previously realised.

Scientists first learned of Enceladus' watery blasts in 2005, when NASA's Cassini spacecraft caught icy particles shooting up through large lunar cracks called 'tiger stripes'. Analysis revealed that the jets contained methane, carbon dioxide and ammonia – organic molecules containing the chemical building blocks necessary for the development of life. It's even possible that some of these gases were produced by life itself, burping out methane deep beneath the surface of Enceladus.

Water is another piece of evidence in the case for possible life on Enceladus. Enceladus is totally encrusted in a thick layer of water ice, but measurements of the moon's rotation suggest that a vast ocean is hidden beneath that frozen crust. Scientists think the spurts of water sensed by Webb and Cassini come from hydrothermal vents in the ocean floor – a hypothesis supported by the presence of silica, a common ingredient in planetary crusts, in the vapour plumes.

NASA scientists are discussing future return missions to seek out signs of life on Enceladus. The proposed Enceladus Orbilander would orbit the moon for about six months, flying through its watery plumes and collecting samples. Then the spacecraft would convert into a lander, descending on the surface of the icy moon. Orbilander would carry instruments to weigh and analyse molecules, as well as a DNA sequencer and a microscope. Cameras, radio sounders and lasers would remotely scan the moon's surface.

Another proposed mission involves sending an autonomous 'snake robot' into the watery depths below Enceladus' surface. The robot, dubbed the Exobiology Extant Life Surveyor, features cameras and lidar on its head to help it navigate the unknown environment of Enceladus' ocean floor.



An artist's impression of plumes on Enceladus

© Getty

MANNED MISSION TO AN ASTEROID

NASA plans to send manned expeditions to near-Earth asteroids in order to discover more about their formation and structure

Asteroids can tell us a great deal about the formation of our Solar System and could be stepping stones to the long-term colonisation of the Moon and interplanetary trips to Mars and beyond. They might well contain water and air that could be used to support deep-space manned missions, and there's the possibility of mining them for their precious metals. They certainly have the potential to enhance human existence, yet there are at least 1,000 dangerous asteroids that pose a risk to Earth.

In April 2010, former president Barack Obama announced that NASA should send a manned mission to an asteroid by 2025. Though this target doesn't look likely, one of NASA's future plans is to use an unmanned spacecraft to capture a 500-tonne, seven-metre (23-foot) diameter asteroid and send it into a high lunar orbit. Here, unmanned spacecraft and manned crews using Orion spacecraft could easily visit and study it in detail. An asteroid capture and return spacecraft would take about four years to reach a suitable asteroid, 90 days to deploy a large capture bag and a further two to six years to take it to the Moon.

A more advanced plan is to use a combination of Orion spacecraft and a Deep Space Habitat (DSH) to go beyond Earth orbit. The habitat would consist of a four-person habitation module and would be suitable for 60-day missions. With an additional Multi-Purpose Logistics Module (MPLM) linked via a utility tunnel and docking module to the habitation module, it could operate for 500 days. These modules would be based on existing and functional International Space Station designs and technology. Either option would be propelled using a cryogenic propulsion stage using liquid hydrogen-liquid oxygen engines, and possibly in future by more advanced ion engines.

The DSH would also carry a small two-person Multi-Mission Space Exploration Vehicle (MMSEV). This would take the astronauts from the DSH to a nearby asteroid to obtain geological samples and carry out science experiments. Testing of a prototype has already been conducted at Johnson Space Center, which involved two astronauts spending three days and two nights living inside it. Using virtual-reality headsets and a rig to suspend the astronauts to reproduce weightlessness, they evaluated simulated extravehicular activities (EVAs) on the surface of an asteroid. Other training projects are dealing with living in deep space for long periods of time.

These plans all depend on funding, but in the long-term, visiting, exploring and mining asteroids could give a tremendous boost to new industries and the further exploration of our Solar System.

"This would take the astronauts to a nearby asteroid to obtain geological samples and carry out science experiments"

1 Grappling arm
The MMSEV has a large window array at the front and carries lights so that crew can easily see and use the grabbling arm, enabling them to explore the asteroid's surface and obtain samples.

2 EVA
Using an airlock at the rear, one crew member can go outside to conduct extravehicular activities on the surface of the asteroid. This could include deploying science experiments and selecting rock samples.

3 Solar panels
The large solar arrays convert sunlight to electrical power. They power all systems in the habitat and charge batteries for emergency backup.

4 Multi-Mission Space Exploration Vehicle
The MMSEV, which looks like the submersible craft used to explore our oceans, will transport a two-person crew to and from the space habitat.

5 Orion spacecraft
Orion can carry four or more astronauts beyond low-Earth orbit, ferrying crew and equipment to and from Earth.

6 Near-Earth asteroid
There are around 10,000 known near-Earth asteroids, 1,000 of which are more than a kilometre (0.6 miles) in size. NASA has identified 40 that could be accessed by manned spacecraft in a year-long mission.

7 Instrument bays
Contains instruments, science experiments, equipment and life-support systems. Airlocks provide easy access to docked spacecraft.

8 Deep Space Habitat
Provides living quarters for four to six crew members for several months.

9 Living quarters
Centrifugal living quarters rotate to create artificial gravity to help maintain the health of the crew.

10 Docking ports
Ports allow Orion and MMSEV spacecraft to dock with the habitat.

© NASA

BIO+

David Levy

Astronomer and writer David Levy has discovered over 20 comets and written 30 books. He has won several awards, including the Amateur Achievement Award of the Astronomical Society of the Pacific.

David Levy

"We knew that this would be a historic comet"

Astronomer David Levy was immortalised for his co-discovery of Comet Shoemaker-Levy 9 – its impact with Jupiter 29 years ago held the world in awe

Interviewed by David Crookes

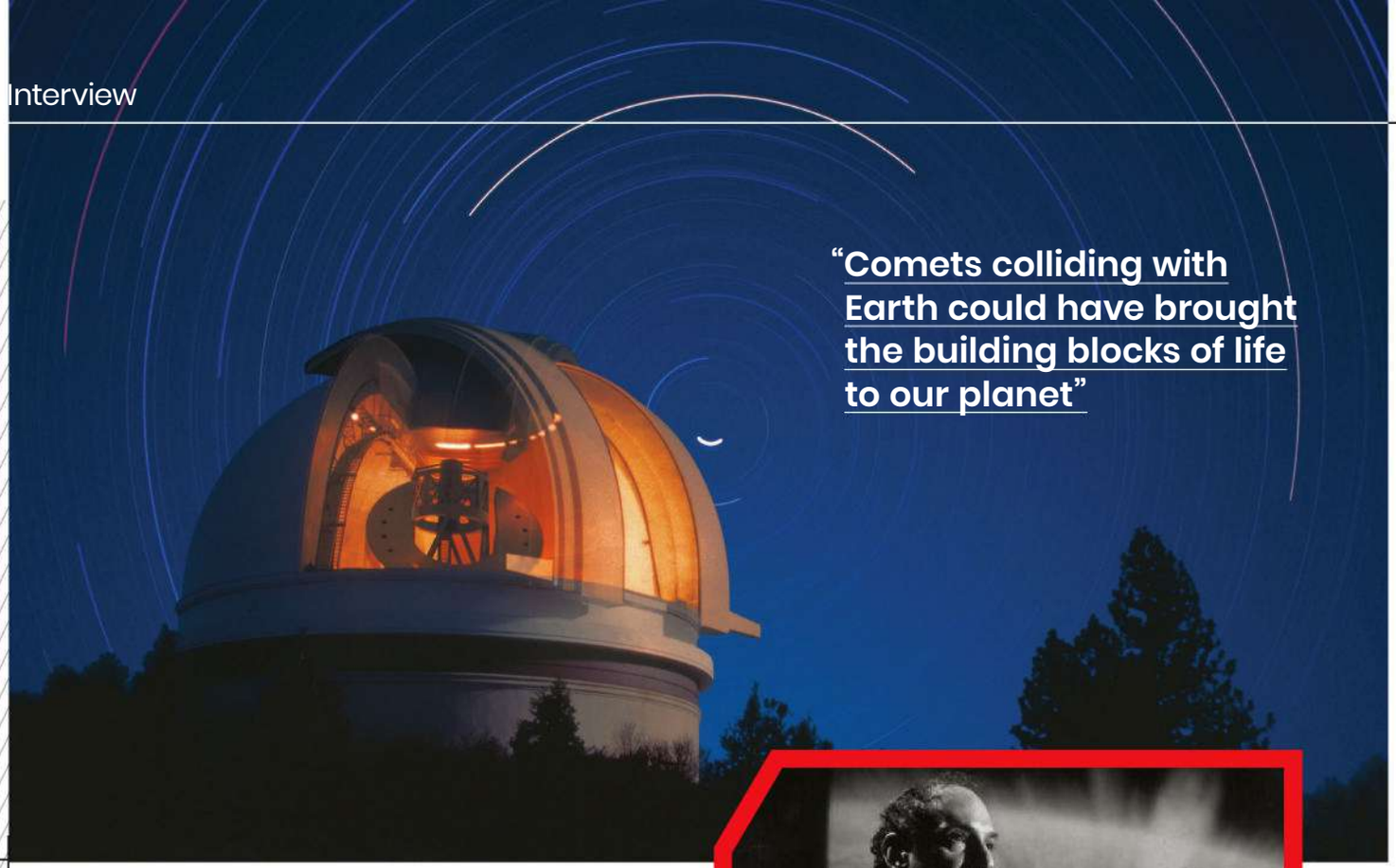
How did you find Comet Shoemaker-Levy 9?
We [Levy and Gene and Carolyn Shoemaker] had been observing together for a number of years as part of a program to discover comets and asteroids that could pose a threat to Earth at some time. We never expected to find this guy. On the night of 23 March 1993, we were observing and actually taking photographs through patchy clouds – it was just before a major weather disturbance. We got our work very much done and taken care of. When Carolyn was scanning the images that we took that night she found what she felt was a squashed comet. It was on two of the photographs that Gene and I had taken, and it was named, as is customary for the discoverers, Shoemaker-Levy 9. That's the short version of how we discovered the comet.

When finding out the comet would collide with Jupiter, did you realise it would be such a historic event?
We knew as soon as we found out that there was going to be a collision that this would be a historic comet. But right away everybody started squealing and yelling that we wouldn't see anything – it would be a dud because things hit Jupiter all of the time and we never see anything. What we didn't realise was that apparently nothing that size had collided with Jupiter within the memory of humanity. The spots that were formed were clearly the darkest and most obvious formations to ever be seen on the gas giant. We started seeing them immediately after the first impact, and when the other pieces collided, they left spots that were even bigger. The largest was left by the fragment known as G, and this turned out to be the most obvious feature ever to be seen on the planet since the invention of the telescope.

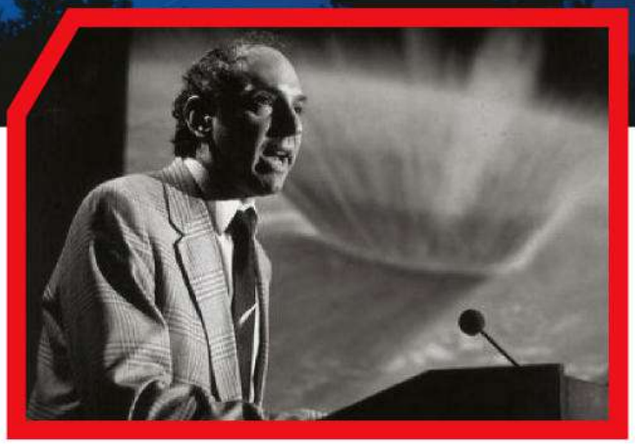
Do you think an event like this could happen again in the future?

Artist's impression illustrating the breakup of the comet

©Royal Astronomical Society



"Comets colliding with Earth could have brought the building blocks of life to our planet"



The comet was discovered in an image taken with the Palomar Observatory's Schmidt telescope

Levy giving a lecture on Comet Shoemaker-Levy 9 at NASA's Jet Propulsion Laboratory

It already has happened, in fact, but not to the same extent. In 2009, I believe, there was a single small object that collided with Jupiter and left a small spot that lasted for a few days – by the way, the Shoemaker-Levy 9 spots lasted for almost a year. Then I think the following year there was another collision that didn't leave a spot, so this is happening a lot more than we thought it would be, although not quite as obvious as a comet that could be discovered in advance of the collisions, as ours was.

Once the impact was over, did it exceed your expectations?
It exceeded them by a huge amount. I remember that a few days into the collisions, the Naval Observatory was open to the public on the grounds of the vice president's residence in Washington. I remember standing in a long line, and people were encouraging me to go forward. I didn't want to, but I did. I finally got in to look through the telescope after about an hour and I was just amazed at what I was seeing – really dark black spots across the entire face of Jupiter. They were so easy to see and so clear and obvious, I could even see them through the telescope's finder.

You've been observing comets for a very long time. Has this particular impact taught you something new about them?
I've been observing and studying comets ever since I was a child. I never actually thought of the idea that comets could collide with a planet with such an effect. Shoemaker-Levy 9 taught us the basic lesson that comets hit planets and they have dramatic effects. It's possible that in the early days of our planet, comets colliding with Earth could have brought the building blocks of life to our planet. The simple blocks of life – hydrogen, oxygen and nitrogen particles – that would eventually become amino acids, and after that RNA and long after that, DNA – the essential building block of life.

Did Shoemaker-Levy 9 change your life? How did you cope with the media reaction?
It was so interesting to be on the front pages of all of the newspapers for a whole week… and all of the TV stations. I remember sitting at NASA headquarters the day before the impacts, being interviewed by maybe 15 to 20 different television stations, one after the other. Then, in the middle of the impacts, I was interviewed again by television stations one after the other. That was really quite an experience. It was something that we felt was causing the world to pause for a moment – to pause from its preoccupation, the normal buzz of the nightly newscast, and look up into space for a moment and contemplate the vastness

© NASA/JPL; Alamy

of the universe, as well as the role of humanity in that universe.

You know, we thought that there were more stars in our galaxy than there are grains of sand on a beach, as well as more galaxies in the universe than there are grains of sand on all of the beaches of the world. Despite that, there's only one of you and only one of me in the entire universe.

How did you start working with the Shoemakers?
Before I wanted to work with them, I'd already built up a reputation as a comet discoverer, having found, I believe, four comets when I met them. I arranged for the Shoemakers to observe at a telescope near Tucson one night – they wanted to try it out.

On the way down from that observing session, I looked back at them and said: "I have something to ask you, but I'm a little afraid to do it." Gene said: "Well, the best way to do it is to just look at us and out with it." I said, "Okay, I would like to observe with you at Palomar. Is that a possibility?" Gene and Carolyn looked at each other, and looked seriously and critically, and Gene laughed and said: "I think that would be possible." I started observing with them about six months later and observed with them from the late summer of 1989 all the way until the end of 1994, and then we had one final session in the spring of 1996.

How hard is it to find a comet? Is it something anyone would be able to do?
It's very difficult, especially now, because part of what we accomplished with Shoemaker-Levy 9 was to get the world interested in this problem of is there an asteroid or comet that could collide with Earth? If there is, we'd better find it. Now there's a lot of money being paid into searching the skies for asteroids or comets that could collide with Earth. We've actually found a couple within a few hours of their collisions with us – not comets, but small asteroids. We missed the one that hit Russia a few years ago because it was very close to the Sun as it was approaching us and we never got to see it, and finally it collided with us very, very rapidly. It didn't do any damage, except a lot of broken windows and the scratches that people got. I don't think there were any fatalities and I think everybody was okay, but it did teach us that Earth is a target and we will be hit again. Let's hope we're not hit by any of the big kinds.

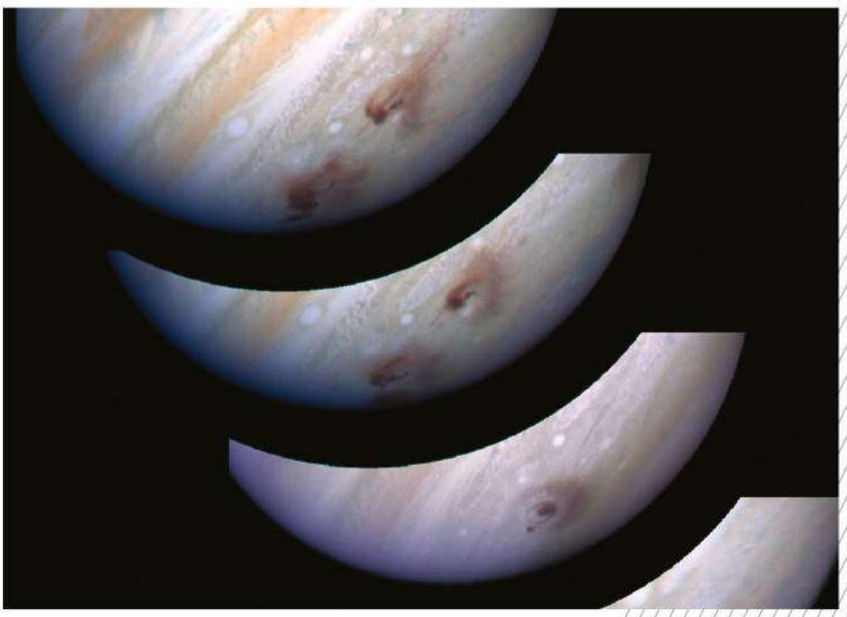
What equipment do you use to locate comets?
I do it in two ways – first with my eye and a 16-inch reflector telescope, but I also take electronic images with five or six other telescopes at the same time. It takes me about an hour to get those telescopes up and going, but once they are, I can relax and do the visual search, and that's a lot of fun. There's a lot of attention that's needed to set up the automated cameras, but once they're up and running it's a beautiful thing for me to be just sitting back with the telescopes and watching the sky for comets. I search the sky by one field of view per second and just move the telescope slowly across the sky towards the east, and I enjoy that very much.

There was a famous astronomer who wrote a book about his own life with comets and he said, and I quote: "I have watched a dozen comets, hitherto unknown, slowly creep across the sky as each one signed its sweeping flourish in the guest book of the Sun". That astronomer was named Leslie Peltier, and it's one of the most beautiful things I have ever heard about comets.

Do you do your observations every night?
When the Moon is not in the sky, I'm usually observing for at least the hour before dawn in the morning.

What's the faintest comet you've ever found?
The faintest one I found was located electronically. It's credited partly to me, but it was actually found automatically by one of our telescopes here at the observatory. Because of that little trick it was not named for us as its discoverers. It was instead named for the observatory. Another example of a comet named after an observatory is Comet ISON, of course, which totally disintegrated before it had the chance to become bright.

What are some of the other Shoemaker-Levy comets like?
We found a total of 13. Nine of them are in orbits that have them coming back again and again, and they are called periodic comets. Of course, the ninth won't come back again because it has collided with Jupiter and is deceased now. We found four others that are not periodic, and they just came across once and never again. So that's 13 comets plus eight that I have discovered myself from my home here – from my telescope and using just my eye and an eyepiece at the telescope. The most recent comet I found that way, visually, was in October 2006, so it's been a long time, but I'm still looking.



Fragment G of Shoemaker-Levy 9 was found to be the most obvious impact site. This mosaic of the Hubble Space Telescope images reveals its evolution

FOCUS ON

CHINA PLANS TO PUT ASTRONAUTS ON THE MOON BEFORE 2030

China and the US are eyeing the same landing sites in the lunar south pole

Reported by Sharmila Kuthunur

China plans to land astronauts on the Moon before 2030 and add a fourth module to its space station. The country's plans for landing on the Moon include a "short stay on the lunar surface and human-robotic joint exploration," Lin Xiqiang, deputy director of the country's human spaceflight agency, said during a news conference at the Jiuquan Satellite Launch Center.

Both NASA and China's space agency are eyeing potential landing sites near the Moon's south pole, where water ice and other resources that could prove to be valuable for lunar settlement and exploration can be found. Xiqiang also announced plans for adding a module to the Tiangong space station, which currently features three modules that were launched one at a time since May 2021 and put together in space. China's plans for its space station, which was completed in November 2022, include hosting a three-member crew at all times for at least a decade. The fifth such crew, including the country's first civilian astronaut, was launched late on 29 May and reached the space station early on 30 May.

The space station's fourth module will be launched "at an appropriate time to advance support for scientific experiments and provide the crew with improved working and living conditions," Xiqiang said. With the addition of the fourth module, the T-shaped space station may look like a cross. In the long run, China plans to add two more sections to its space station, which would bring the total number of modules to six. While NASA has maintained that the "cooperation with China is up to China," the Wolf Amendment, a restrictive legislation passed by Congress in 2011, bars NASA – a federal agency – from using funds from the federal budget to engage in direct cooperation with the Chinese government. "Our country's consistent stance is that as long as the goal is to utilise space for peaceful purposes, we are willing to cooperate and communicate with any country or aerospace organisation," Li Yingliang, technology director of the Chinese human spaceflight agency, said. "Personally, I regret that the US Congress has relevant motions banning cooperation in aerospace between the US and China. I very much regret that personally."

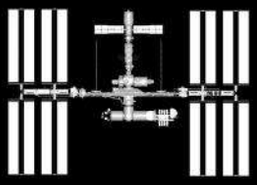
An illustration of Chinese astronauts on the Moon

NASA's Artemis III aims to launch astronauts for a crewed landing mission near the lunar south pole in late 2025, while China's Chang'e 7 robotic mission, which aims to soft land a rover in the same region, is scheduled for 2026. And a few of the potential landing sites for both missions are the same.

This overlap, which will require both countries to collaborate to some extent, is in part due to the preferred lighting conditions at the lunar south pole, while being close enough to permanently shadowed regions where water ice and other useful resources are thought to be present. "NASA discusses its plans for lunar exploration at various multilateral forums, such as the ISECG [International Space Exploration Coordination Group], of which China is a member," a NASA spokesperson said last year.

SPACE STATION COMPARISON

International Space Station



Maximum length: 109 metres (357.6 feet)
Mass: 420 tonnes
Life span: 26 years if deorbited in 2024
Crew size: Six normally, or nine short-term
Initial launch date: 1998

Chinese space station

Maximum length: 37 metres (121.4 feet)
Mass: 90 tonnes
Life span: Ten years or more
Crew size: Three normally, or six short-term
Initial launch date: 2021

Mir

Maximum length: 31 metres (101.7 feet)
Mass: 130 tonnes
Life span: 15 years
Crew size: Three normally, or six short-term
Initial launch date: 1986

1 Tianhe core module and living quarters

The core module of the space station, Tianhe houses the main living quarters for crews of three taikonauts during visits up to six months at a time.

2 Tianhe docking hub

Tianhe houses a docking hub to allow for the joining of experimental modules, visiting Tianzhou cargo vessels and crewed Shenzhou spacecraft.

3 Wentian

This module is primarily used for scientific research, as well as acting as a working and living space during an emergency.

4 Mengtian

Similar to Wentian, both modules possess an airlock chamber to support extravehicular activities, as well as a small mechanical arm each.

5 Solar arrays

The solar arrays provide electrical power to the space station. When the space station passes into Earth's shadow, stored energy is used to power it.

6 Tianzhou cargo ship

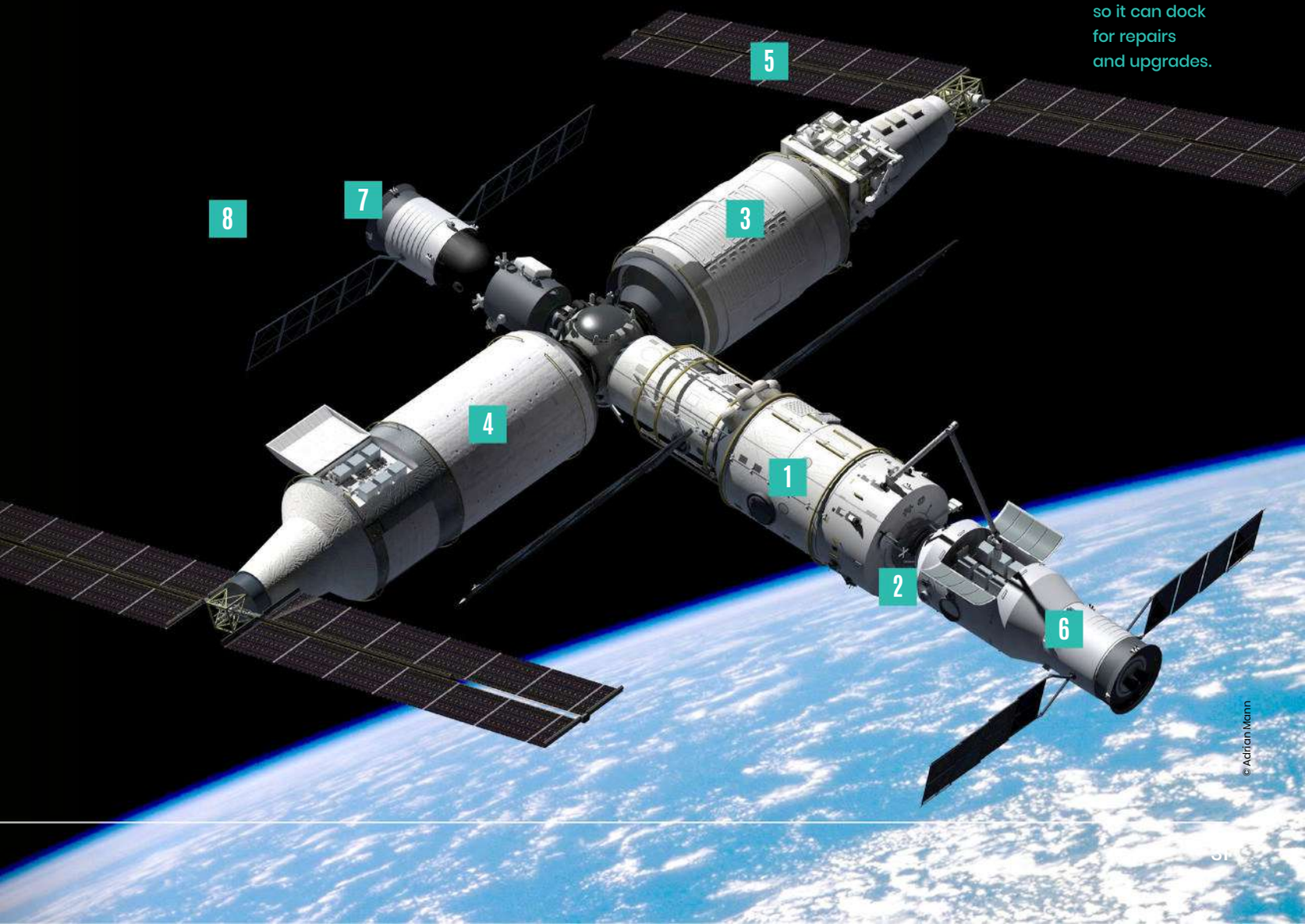
This cargo freighter resupplies the space station with fuel and essentials. It acts in a similar fashion to Russia's Progress or SpaceX's Cargo Dragon capsule.

7 Shenzhou spacecraft

This ferries taikonauts to and from the space station. It has been used in previous missions to space laboratories Tiangong-1 and 2.

8 Xuntian space telescope

Currently under construction, Xuntian will have a field of view 300 times larger than that of Hubble. Xuntian will be placed in orbit close to the space station so it can dock for repairs and upgrades.



© Adrian Mann

CAN SPACE EXPLORATION REALLY BE ETHICAL?

More than 60 years after Russian cosmonaut Yuri Gagarin became the first human to travel beyond Earth's atmosphere, human exploration and exploitation of space isn't just a matter of technological innovation... it continues to raise many ethical issues

Reported by Paul Cockburn

Science fiction highlights some ethical issues of space exploration in entertaining ways

Astrophysicist and lifelong space travel enthusiast Erika Nesvold was participating in what she describes as "a really fun" research program, based at NASA's Ames Research Center in California, when she experienced something of a "conceptual breakthrough". "We got introduced to a lot of people working in the commercial space industry," she explains. "At the time, space mining was the really big thing everyone was talking about. I met several of the entrepreneurs and had conversations where I would ask them about things like labour rights or environmental protection and got sort of dismissive responses, which I found concerning."

Nesvold decided to consult some experts in the field by launching a podcast called *Making New Worlds – Exploring the Ethics of Human Settlement in Space*. This project, she says, "was a lot of fun", enabling her to explore many of the themes which she has since expanded upon in her first book, *Off-Earth: Ethical Questions and Quandaries for Living in Outer Space*. She has also co-edited *Reclaiming Space: Progressive and Multicultural Visions of Space Exploration*, an anthology of essays exploring similar themes.

"I'm certainly neither the first nor only person to start thinking about space ethics," she insists. "Everyone I've met who's interested in space ethics started thinking about these ideas independently, felt alone in what they were beginning to be worried about and were so happy to meet other people thinking along the same lines." Along with astronomer Lucianne Walkowicz, Nesvold co-founded the nonprofit organisation The JustSpace Alliance in 2018, which works towards "an inclusive, ethical future, both on Earth and beyond". As well as promoting education and debate, "one of the things we do is serve as a hub to connect all these people into a network to collaborate about various aspects of this problem," she says.

What exactly are the issues Nesvold and others are concerned about? One big concern is simply how we, as a species, will interact with the space environment. "That's not just for practical reasons, but also ethical ones: how do we share the space environment and its resources with each other? That's an ethical question as well as a political one," she says. "Also – this is something philosophers love to talk about – what is the intrinsic value of the space environment itself? What do we owe the environment in terms of protection, or any potential non-terrestrial life? This is something astrobiologists are particularly concerned about, not just for the scientific integrity of it, but if there's life – even just microbial life

© Getty

ANTARCTICA

In 2020, researchers from Australia and China concluded that Dome Argus in Antarctica was the best place on Earth to observe space. Cold, dark, high and remote, it exemplified how the southern pole is arguably the nearest terrestrial environment we have to what exists beyond our thin atmosphere. "Antarctica is a great case study for space," Nesvold agrees, "because its environment is so hostile, although it's still quite a lot nicer than actual space. Also, it's an environment that has a lot of scientific value – scientists are very interested in going out and studying it – and it's chock full of mineral resources. There's always been this tension between the scientific interests and the people who would be very happy to extract minerals from Antarctica.

"The legal history of Antarctica is a very interesting case study for how we could approach space, because they have managed to put a ban on mineral extraction," she says. "Watching how they did that, and how it was achieved through some environmental activism, is pretty fascinating. No analogy is perfect, but Antarctica is a good one."

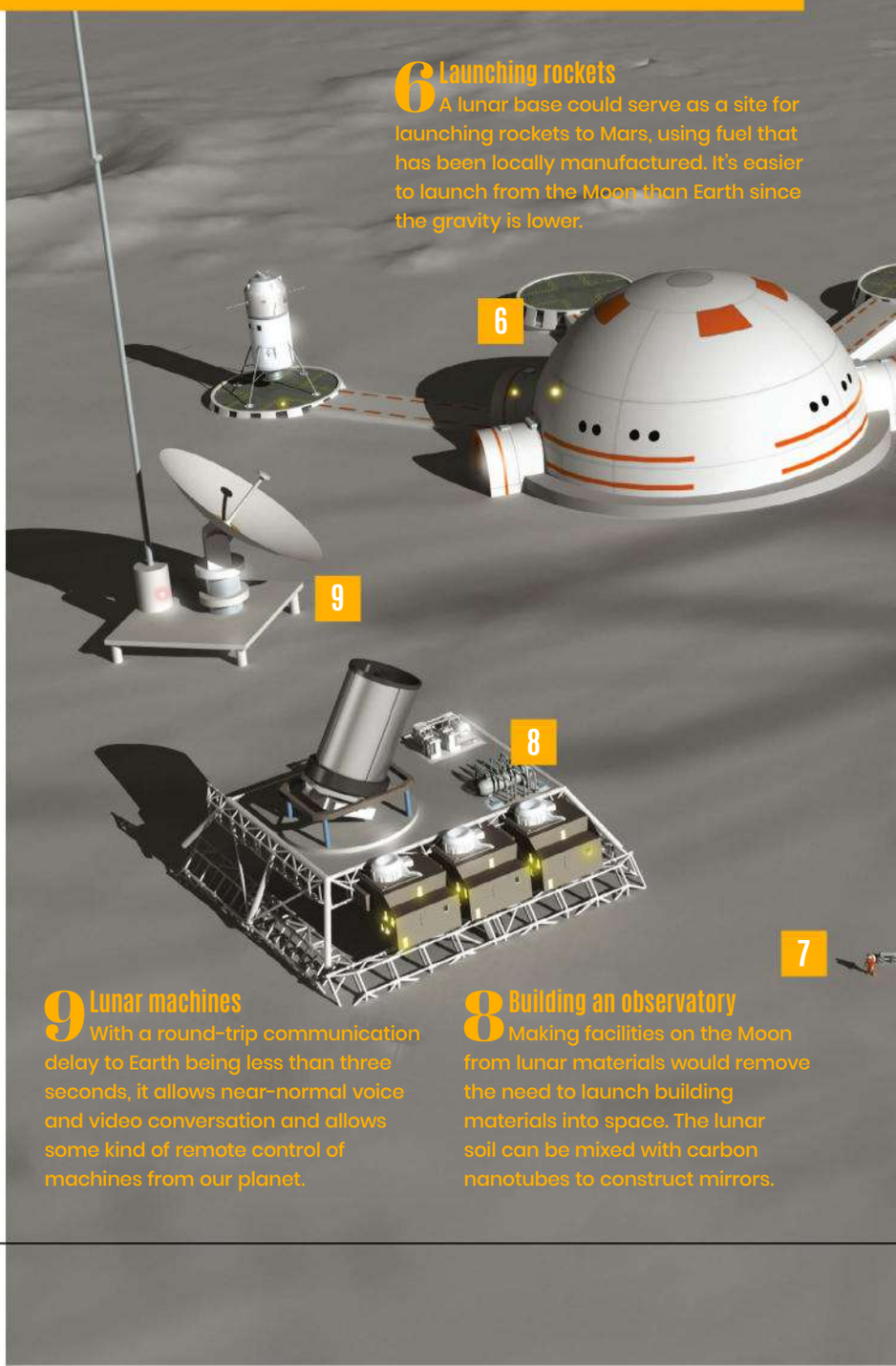
Another potential analogy is Earth's oceans beyond any nationally declared territorial waters. "This is often brought up by space lawyers because the international oceans aren't claimed by any particular territory, and in space, according to the Outer Space Treaty, no nation can claim territory in space," Nesvold says.

– do we owe a certain level of protection to it? Also, what do we owe future generations? Do we need to preserve some of the space environment for them?" Another big category touches on what the French philosopher Jean-Paul Sartre summed up in his famous quote: "Hell is other people." With increasing numbers of people living and working in space, how will we live with each other? "We will have to figure out how we will form new communities together in environments that are so much on the edge of survival, so harsh."

Discussing the ethical aspects of space exploration may be relatively new, but Nesvold believes we should've been talking about them well before now. "Of course some people were – there have always been some people commenting on whether we should be exploring space or conducting military operations or resource extraction in space. There's always been criticisms of that," she says. "And there's always been science fiction; science fiction writers have been space ethicists since before people have been going into space, as they've thought through all these potential scenarios and what we can learn from them."

Taking an ethical stance on the issues now isn't just a case of better late than never, she accepts. "I think this is an important time to talk about it, even regarding things that might not turn up for generations," she says. "For example, in my book I have a whole chapter on reproductive rights in space. As far as I know there's not anybody planning to attempt human reproduction in space for some time, and we're probably a few generations away from having the kind of outposts in space where we would need to worry about it. But I think it's still crucial to think about those things now and to start having those conversations so that when it does come up, we've all hashed out a lot of these ideas."

Although space exploration was previously the sole preserve of national governments and political superpowers, it's increasingly in the hands of private companies. "The growth of the private space industry



6 Launching rockets
A lunar base could serve as a site for launching rockets to Mars, using fuel that has been locally manufactured. It's easier to launch from the Moon than Earth since the gravity is lower.

9 Lunar machines
With a round-trip communication delay to Earth being less than three seconds, it allows near-normal voice and video conversation and allows some kind of remote control of machines from our planet.

8 Building an observatory
Making facilities on the Moon from lunar materials would remove the need to launch building materials into space. The lunar soil can be mixed with carbon nanotubes to construct mirrors.

COLONISING THE MOON

Our lunar companion could serve as a stepping stone in surviving on other worlds in the Solar System

1 Close to home
Thanks to its proximity to Earth, the Moon is the most obvious place to colonise.

2 In an emergency
A short transit time of three days, which astronauts could improve on, allows emergency supplies to quickly reach a Moon colony from Earth or allow a crew to quickly leave the Moon and head back to our planet.

3 Moon farms
A lunar farm would be stationed at the lunar north pole, allowing for eight hours of sunlight per day during the local summer, achieved by rotating crops in and out of the sunlight. Beneficial temperatures, protection from radiation and the insects needed for pollination would need to be artificially provided.

4 Lunar bases
Bases on the surface would need to be protected from radiation and micrometeoroids. Building a Moon base inside a crater would provide shielding.

5 Transport on the Moon
The ability to transport cargo and people to and from modules and spacecraft would be essential on the Moon. Rovers are likely to be useful for terrain that's not too steep or hilly, while permanent railway systems could be used to link multiple bases. Flying vehicles would be used for hard-to-reach areas.

7 Humans in low gravity
Colonising the Moon's surface means that we can find out how the human body responds to long periods of low gravity, as it's one-sixth that of Earth's. We can then use this information to plan a viable colony on Mars.

© Getty

has been celebrated for a number of reasons," Nesvold says. "It expands the number of people who have the ability to go into space, slightly. It's not just people who have been hired and passed the tests... it's now those people and some very rich people – a small expansion. I've heard people in the private space industry refer to this growth as the 'democratisation of space', and I think that's quite an exaggeration. To me the 'democratisation of space' would mean that everybody has an equal opportunity to go into space, to conduct business in space, and we're not there yet.

What is significant is that we're now seeing different reasons for space exploration. "Certainly, people who are very into capitalism would argue that commercialisation leads to more innovation and cheaper rockets and what not. But one of the problems of moving towards a profit-motivated space industry is that these organisations are motivated solely by profit. At least in the US, they are legally obligated to care about their duties to their shareholders above all else. We could end up in very common situations which we see over and over again here on Earth, where companies that are so motivated by profit end up cutting corners, leading to a lot of

SCIENCE-FICTION PRECEDENTS

For many people, the nearest they will get to thinking about space ethics is science fiction, which Nesvold believes has been doing some good work preparing us for the ethical challenges we will face settling beyond low-Earth orbit.

"I think science-fiction storytellers have been doing amazing work on that for decades – potentially even centuries, depending on how you want to define science fiction," she says. "Science fiction, as an industry, hasn't created as many diverse viewpoints as it should have, so that's a weakness of the science fiction 'canon', but that doesn't mean people from all cultures haven't been writing and talking and thinking about these issues for a long time."

Popular franchise *Star Trek* has even evolved its own core ethical principle regarding first contact with alien species: non-interference in any culture which has not yet joined the galactic club by developing 'warp drive'. "That's an example of why science fiction is so useful – it provides these cultural touchstones, these shorthands," says Nesvold. But even people who don't read or watch science fiction can easily get a handle on human rights issues in space. "All of these problems mirror the problems that we already have on Earth," she points out.

WHY WE SHOULD MINE ASTEROIDS

Asteroids provide natural resources to fuel the exploration of space and prosperity on Earth as our population continues to grow

Finding water

A single asteroid could produce enough fuel for every rocket launched throughout history.

1 Water-rich asteroid
A single 500-metre (1,640-foot) asteroid would produce over £3.47 trillion ($5 trillion) worth of water for use in space. Sending water to space from Earth is costly, as rockets are heavier the more water they have to carry.

Uses of water in space:

- Fuel for rockets
- Air to breathe
- Water to drink

2 Infinitely rich
Asteroid mining will provide an almost-infinite supply of platinum metals and water that can support us both on and off Earth.

Metal mining

This type of asteroid contains more platinum metals than we have currently mined from Earth to date.

3 Platinum-rich asteroid
A 500-metre (1,640-foot) platinum-rich asteroid is worth about £2 trillion ($2.9 trillion), which is more than our yearly output of platinum.

Uses of platinum on Earth:

- Reduces the cost of electronics
- Transport that requires electricity
- Creating a greener Earth

environmental damage and to worker exploitation. That is potentially a big concern with people working in space for commercial companies. Their work sites will be very hazardous, isolated and remote. It will be hard to monitor work site conditions. It might be very difficult for workers to leave or to go on strike in a space settlement, so embracing the commercial space industry, and the idea that profit-motivation is finally what's going to get us out there, also sets us up for a lot of those risks."

NASA's current Artemis lunar mission plans "to land the first woman and first person of colour" on the Moon, somewhat underscoring the lack of human diversity anywhere beyond low-Earth orbit. Understandably, Nesvold believes that it's crucial to ensure as much diversity as possible when it comes to discussing the cultural and legal frameworks for future space exploration. "I think it's crucial to get as much input as possible, for two reasons. Firstly, because it's the right thing to do. Space is for everyone. In the Outer Space Treaty from 1967, space is referred to as the province of all humankind, and there's a lot of language in there about the benefits of space being for all humankind. But in order to make sure those benefits are distributed, it helps very much to make sure that everyone's input is being sought out and being considered, to ask what kind of benefits we want and how we balance that with the potential harms.

"Secondly, if you're talking about building new communities in a very strange land, it helps to have a lot of input into how different cultures view land, view space, view responsibilities to each other and our environment and to future generations," she says. "There's no single culture which has figured all of this out perfectly; lots of different cultures – because of where they are in the world and what their history has been – have really valuable information, knowledge and views on how to live in isolated, remote, harsh environments. They've got a lot of experience from their own cultures of how to thrive in those conditions. Even setting aside the ethical reasons for this, there are just practical reasons to get as much input as possible."

If many of those involved in the space sector have yet to take on board the ethical considerations, this doesn't mean there's a complete lack of activity in the field. "There's a ton of space lawyers working on space regulations; it's a big field right now," she says. "But ethics doesn't just inform the legal system. It also informs our organisational cultures and even things like design – how we design the technology in our spacecraft and habitats needs to be informed by things like accessibility for disabled astronauts or freedom of movement. Even space architects have to worry about these issues too."

Despite the podcasts, books, media interviews, articles and The JustSpace Alliance, pushing for more forthright discussions of the ethics of future space exploration and settlement is not yet Nesvold's day job. She currently works as an astrophysicist engineer for the physics-based space simulator *Universe Sandbox*. When she first became concerned about some people's apparent lack of interest in the ethical issues inherent in space exploration, Nesvold was well aware that, given her own somewhat technical background, she needed to consult the experts. And she did.

But what does she hope to achieve in the future? "My goal at the moment – besides talking to as many different people as possible – is to use the platform I've helped build to amplify the work of so many people who are already working on these issues, both in the context of space and not in the context of space," she says. "A lot of the social scientists and activists I've talked with hadn't thought about their work in the context of space, but have so much to contribute based on their expertise. That's something I'm hoping to do more of in the future – help provide a platform for all those people."

HISTORY

It was the Spanish-American writer and philosopher George Santayana who famously suggested that "those who cannot remember the past are condemned to repeat it." When it comes to humanity's exploration of space, Nesvold firmly believes that our own history on Earth is the best lesson available – if only to remind us about what not to do.

"History teaches us about ourselves," she says, "and by history I also mean the fields of sociology and anthropology, people who have really studied how humans have formed societies, how those societies have thrived or crumbled in the past and what lessons we can learn from that so that we don't end up just accidentally repeating all of those mistakes in the future in space. That would just be a waste of a lot of effort and lives. History, I think, is a fantastic teacher. We just have to make sure we're consulting the experts who actually have that expertise to provide for us."

Not least because many of the people, organisations and companies advocating for space settlement are already referencing history themselves – or at least a mythologised version of history. "I've heard people refer to... well, the term 'space colonisation', of course, but also 'manifest destiny in space', or people who are excited about space as a 'wild, wild west' in legal terms, meaning less regulation. All of these references are very enthusiastic, and I would argue they are misguided because they don't recognise the harms that were caused by a lot of the parts of history that they're referencing. "It's not just a matter of 'Oh, they're getting history wrong'," Nesvold says. "The problem is that if you get your history wrong, then you'll probably end up repeating that history."

Paul Cockburn
Space science writer
Paul has been writing about and keeping up to date with the latest research in science, technology and space for more than 25 years.

© Getty

THE SPACE RACE

It was the growth of the rivalry between the United States and the USSR that saw the need for the Outer Space Treaty

- USSR
- USA

There remains a lot of interest in mining valuable mineral resources from asteroids

Low-Earth orbit

24 April 1990
The Hubble Space Telescope is sent into Earth orbit to image the universe.

15 November 1988
The first and only flight of the Soviet Buran spacecraft.

20 February 1986
A basic module of the orbital station Mir was launched.

12 April 1981
The world's first Space Shuttle, Columbia, was launched.

20 August and 5 September 1977
Voyager 1 and Voyager 2 were launched on a journey outside the Solar System.

17 July 1975
The very first docking between the US' Apollo and the Soviet Union's Soyuz.

14 May 1973
Launch of the very first American space station, Skylab.

19 April 1971
The world's first space station, Salyut 1, was launched.

17 November 1970
The first planetary rover landed on the Moon.

20 July 1969
The landing of astronauts on the Moon.

31 March 1966
The launch of the very first satellite to orbit the Moon.

3 June 1965
America's first spacewalk was made by Ed White.

18 March 1965
Alexei Leonov became the first person to enter open space.

16 June 1963
The first flight of female cosmonaut Valentina Tereshkova.

20 February 1962
The first orbital manned flight, by John Glenn.

12 April 1961
Yuri Gagarin made the first manned spaceflight.

31 January 1958
Launch of the first American artificial satellite.

4 October 1957
Launch of the very first artificial satellite.

1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998

© Adrian Mann; NASA; ESA; T.M. Brown (STScI); SpaceX; Blue Origin; ULA

WORLD OF KNOWLEDGE

BUY YOUR ISSUE TODAY!
REAL CRIME
DEATH
HISTORY of WAR
TRENCH FEVER
Super spreaders on the Western Front
ALL ABOUT SPACE
JAMES WEBB SPACE TELESCOPE: 12 SURPRISING DISCOVERIES
SHOULD WE COLONISE MARS?
WHAT IS CAUSING THE BIGGEST EXPLOSION IN SPACE?
ALL ABOUT HISTORY
GALILEO THE HERETIC
SECRET SOCIETIES
WHERE DOES YOUR POO GO?
HOW IT WORKS
BODYCAMS, TASERS AND SMART POLICE CARS
WHY WE NEED FLIES
LIVING ON THE MOON
WHAT IF THERE WAS NO GRAVITY?
HOW THIS FUNDAMENTAL FORCE BINDS YOU TO THE UNIVERSE AND EVERYTHING IN IT
GIANT ROAD-PAVING MACHINE
WHY RAIN SMELLS
ANIMAL PREGNANCIES
INSIDE A CLASSIC F1 RACE CAR
HOW CARS ARE RECYCLED
GALILEO'S GREATEST DISCOVERIES
WHAT'S HIDDEN UNDER LONDON?
From bomb shelters to abandoned stations
WHAT IF GUTENBERG'S PRESS FAILED?
ASSYRIA'S FORGOTTEN EMPIRE
SCIENCE TECH ENVIRONMENT SPACE HISTORY TRANSPORT

PRINT and DIGITAL subscriptions available at

www.magazinesdirect.com

INSTANT EXPERT

TIME DILATION

What happens to time when travelling at extreme speeds? We ask a scientist to break it down in terms of twins

Martin and Carlos are identical twins. Well, almost. While Martin is a medical doctor, Carlos is an astronaut about to travel to Alpha Centauri, the nearest star system to our own, at speeds nearing that of light. Just before takeoff, Martin and Carlos synchronise their watches, and Carlos reminds Martin that Einstein's theory of special relativity predicts 'time dilation' – that is, that watches moving at a constant high speed appear to tick at a slower pace.

This gets Martin thinking... with Carlos moving rapidly, his watch will run slower, which means that he will be younger upon his return. But from Carlos' perspective Martin will be the one moving at high speed, so Martin's watch will appear to run slower, and so it is Martin who should stay younger. This is the famous 'twin paradox', which is not really a paradox. How is this possible? First, even in relativity the time and space intervals assigned by observers to pairs of events – like two successive ticks of a clock – do not necessarily match. There is an unambiguous map between the coordinates of events seen by different observers in relative motion.

The key point in our example is that the events defining two successive ticks in Martin's clock – which happen at the same point in Martin's reference frame – do not happen at the same point in space from Carlos' perspective, because he sees Martin's clock in motion. Carlos cannot compare directly the ticks of Martin's watch to the ticks of his own watch, because they take place at different points in space. But surely they could compare the ticks when they happen at the same point, for example just before and just after the trip.

For Carlos' ship to return, it has to change course in the middle, which implies the action of a force, and then special relativity does not apply. In this case it is Einstein's general theory of relativity that tells us that Carlos will stay younger. Sorry, Martin!

BIO
DR CARLOS TAMARIT

Tamarit is a physicist at the Technical University of Munich, Germany, who focuses on the theoretical physics of the early universe. His extensive knowledge in particle physics makes him more than qualified to explain the complexities and stranger side of the cosmos.

> "With Carlos moving rapidly, his watch will run slower, which means that he will be younger upon his return"

1 The start of the journey

Before Carlos sets off in his spaceship, destined for Earth's nearest star system Alpha Centauri at a distance of four light years away, he and Martin synchronise their watches. In this scenario, both Carlos and Martin are in the same frame of reference, experiencing the same motion of time and space, and time dilation has yet to interfere.

2 Martin's experience

Martin remains on Earth, travelling at speeds nowhere near as fast as Carlos. From Martin's point of view, Carlos' watch is ticking slower as he travels at speeds close to that of light on his way to Alpha Centauri. While Martin carries on his day as a doctor, Carlos is ageing slower.

3 Carlos' experience

Carlos is now on his journey, travelling at speeds 60 per cent that of light. This equates to 1 billion kilometres per hour (670 million miles per hour). But from Carlos' point of view he is the one whose watch is ticking normally – Martin's is the one ticking slower as he and the Earth travel away at incredible speeds.

4 Difference on arrival

On Carlos' arrival, special relativity stops and the general theory of relativity comes back into play. Time dilation has taken an effect on Carlos', and while the journey took over 160 months to complete from Martin's point of view, the journey only took 128 months from Carlos' perspective. This means that as Carlos steps down from the spaceship, he is now 32 months younger than his twin.

© Nicholas Forder

ALL ABOUT SPACE | Subscription offer

SPECIAL
SUBSCRIPTION OFFER
SUBSCRIBE FOR OUR BEST SAVINGS

SAVE 45%

JAMES WEBB SPACE TELESCOPE: 12 SURPRISING DISCOVERIES
ISSUE 145
AUGUST 2023
ALL ABOUT SPACE
BEYOND PLUTO
FROM PLANET X TO OBJECTS FROZEN IN TIME
WHAT TRULY LURKS OUTSIDE THE SOLAR SYSTEM'S CHAOTIC FRONTIER
SHOULD WE COLONISE MARS?
WHAT IS CAUSING THE BIGGEST EXPLOSION IN SPACE?
INTERVIEW: WHEN A COMET HIT JUPITER
WHY THE UNIVERSE IS MAGNETIC
THE TWIN PARADOX
ALL ABOUT SPACE
SUBSCRIBER EDITION
BEYOND PLUTO

Reasons to subscribe...

- Brilliant value – save on the cover price
- Delivered direct to your door
- Never miss an issue
- Exclusive subscriber-only covers

Subscribe now

www.magazinesdirect.com/AAS145
or call 0330 333 1113 and quote B85K

PRINT ONLY

Delivered direct to your door for £9.83 every three months

PRINT AND DIGITAL

Delivered direct to your door and device for £13.58 every three months

***Terms and Conditions:** Offer closes 31 October 2023. Offer open to new subscribers only. Savings are based on cover price and annual subscription rate. We will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. For full terms and conditions, visit **www.magazinesdirect.com/terms.** For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday to Friday 08:30 to 19:00 and Saturday 10:00 to 15:00 UK time or e-mail: **help@magazinesdirect.com**. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

THE FORGOTTEN FORCE

A seemingly weak magnetic entity could have made all the difference in our universe's evolution

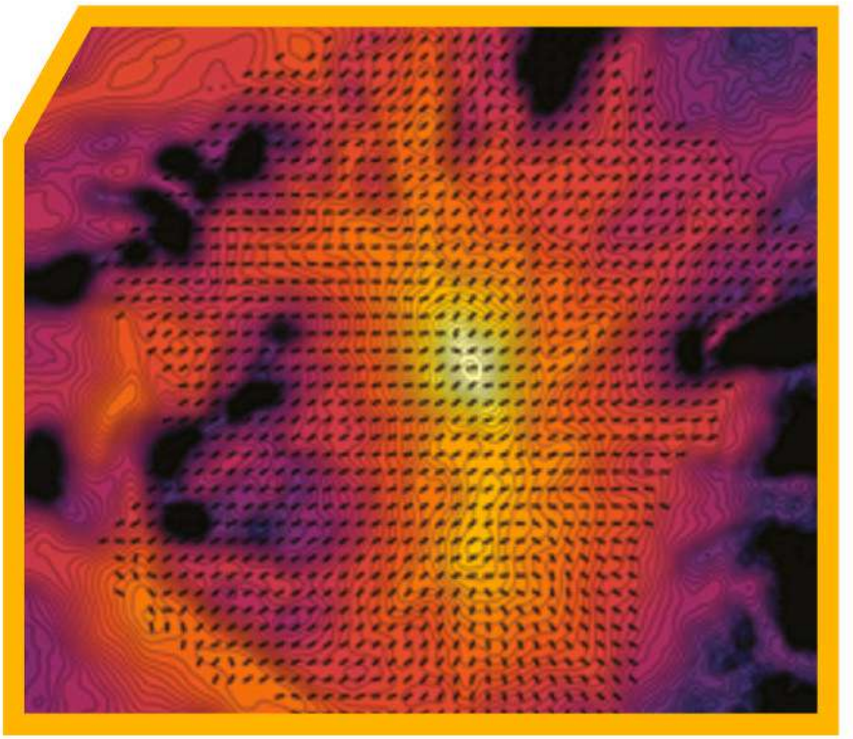
Reported by Abigail Beall

Earth is held in its orbit around the Sun, like other planets around their own stars. Stars themselves are held in galaxies by larger, more massive objects like the supermassive black hole at the centre of the Milky Way. The glue that holds galaxies together is the force of gravity. Yet gravity isn't the only force that matters when it comes to the structure of galaxies and the space between them. For years, interstellar magnetic fields were thought to be so weak they made no difference to how our galaxy evolved. However, research is increasingly showing that magnetic fields in galaxies are important to the way space is shaped.

While the effects of our own planet and star's magnetic fields can be felt on Earth, the magnetic fields of galaxies are much weaker. In fact, physicists didn't expect galaxies to have their own magnetic fields until they were first discovered in 1949, when the polarisation of light coming from stars was measured – caused by a magnetic field. The grains of dust in interstellar space are lined up in one direction, like millions of tiny compasses pointing north, creating this polarisation.

Now we know much more about these magnetic fields, but much still remains a mystery. Stretching out in the vast nothingness of space, interstellar magnetic fields can be weaker than fridge magnets, but their effect is very important. There are a few things that make more sense when this tiny effect is taken into account. Even though it's a small effect, any kind of magnetic field would have an impact on the way charged particles move, therefore altering the shape of the galaxies and the universe.

Magnetic fields permeate through interstellar space. Regardless of their small size, they affect the evolution of galaxies and galaxy clusters and make up a significant part of the pressure of interstellar gas. They're also essential for the onset of star formation and can control the density and distribution of cosmic rays throughout the interstellar medium, since cosmic rays are made up of charged particles.



The structure of the magnetic field in Orion's star-forming region

Galaxies have their own magnetic fields. The Milky Way's overall magnetic field is a few microgauss. This is around 100,000 times smaller than the field at Earth's surface. Our own galaxy's magnetic field is maintained and made stronger by a dynamo – charged particles move across the magnetic field as the galaxy spins,

> "We don't know if this [field] comes from 'astrophysics' or if it comes from 'cosmology'" **Bryan Gaensler**

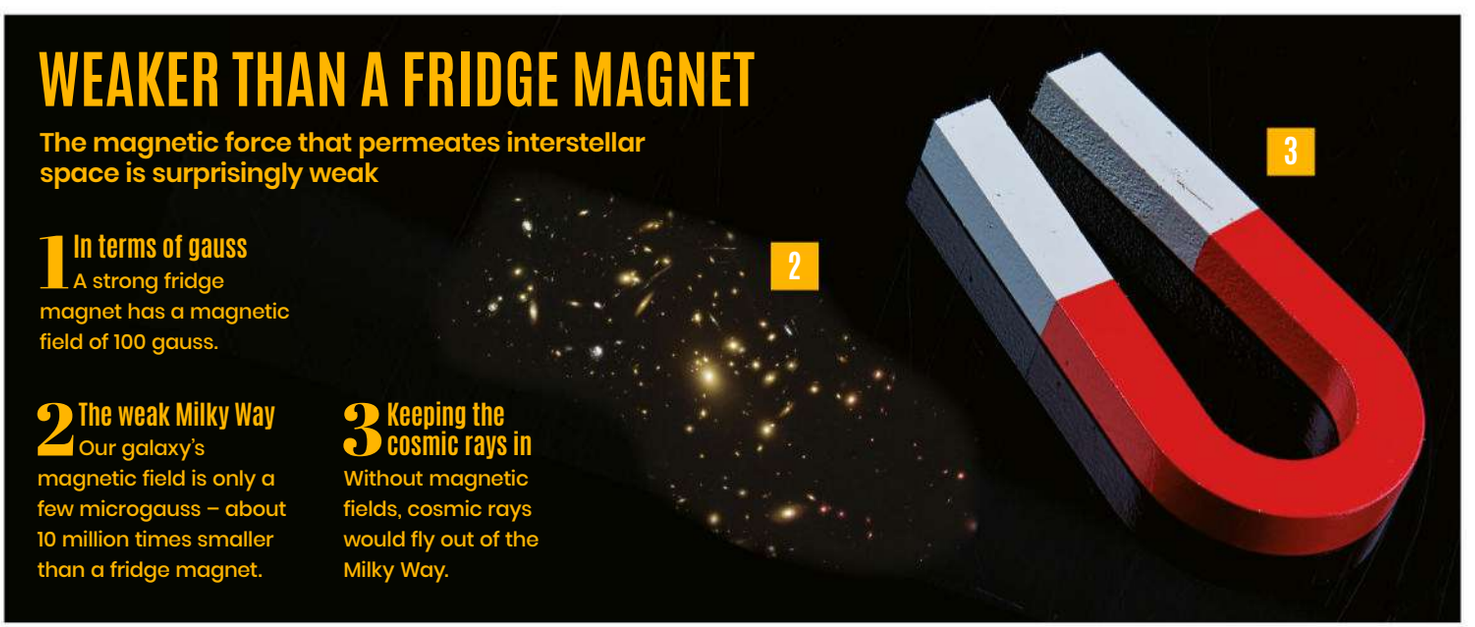
WEAKER THAN A FRIDGE MAGNET

The magnetic force that permeates interstellar space is surprisingly weak

1 In terms of gauss
A strong fridge magnet has a magnetic field of 100 gauss.

2 The weak Milky Way
Our galaxy's magnetic field is only a few microgauss – about 10 million times smaller than a fridge magnet.

3 Keeping the cosmic rays in
Without magnetic fields, cosmic rays would fly out of the Milky Way.



© NASA; R. Beck, MPIfR; NRAO/AUI/NSF

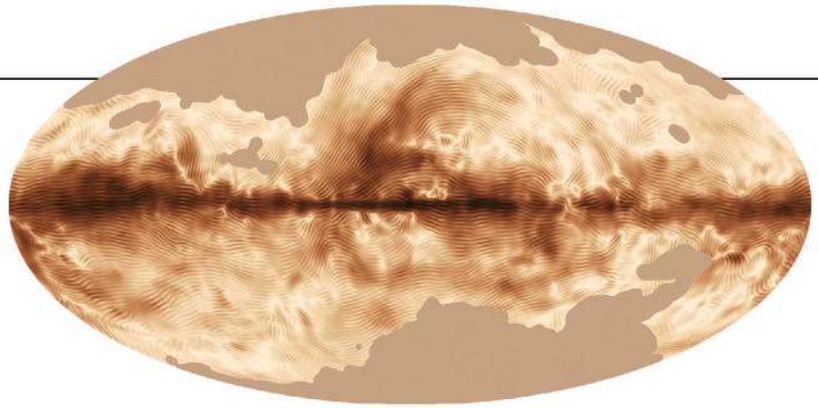
creating an even stronger magnetic field. But our galaxy isn't the only one to have its own magnetic field. Much younger galaxies have shown evidence for them too. However, one mystery remains – how the magnetic fields got there in the first place.

"These models do indeed require a seed magnetic field," says Lawrence Widrow, professor of astronomy at Queen's University in Kingston, Canada. "That is, they can amplify an existing field but can't generate magnetic fields when none exist." How strong these initial seed fields must have been is unknown, says Widrow, because we do not know how long each galaxy has taken to build up the magnetic field it currently has now.

The question of where these seed magnetic fields arose from comes down to two options, says Professor Bryan Gaensler from the Dunlap Institute for Astronomy and Astrophysics at the University of Toronto. "There needs to be some sort of initial seed field," he says, "but we don't know if this comes from 'astrophysics' – from stars, gas clouds and black holes creating and then expelling their magnetic fields – or if it comes from 'cosmology' – some exotic process in the early universe that generated weak magnetic fields."

There have been numerous proposals for generating primordial fields through cosmology. In 1988, Widrow and his colleague Michael Turner published a paper that said these kinds of magnetic fields could be produced in the very early universe, during an epoch of inflation when space expanded exponentially. Inflation is an important time in terms of the development of the universe – it is thought that large galaxy structures were caused by quantum fluctuations in energy during this epoch. However, the theory isn't straightforward. "Our proposal required modifications to the laws of electromagnetism, and therefore requires some rather exotic physics," explains Widrow.

When it comes to astrophysics, there are also options: "You can produce magnetic fields in the first generation of stars



The magnetic field of our galaxy as seen by the ESA's Planck satellite

THE FUNDAMENTAL FORCES OF THE UNIVERSE

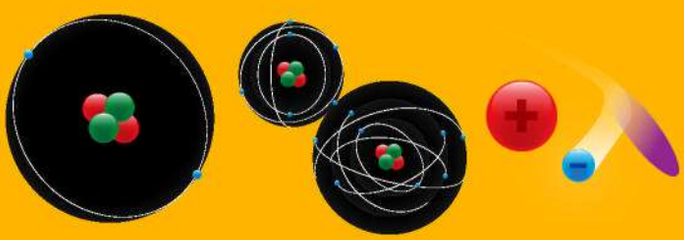
There are four forces responsible for every interaction in the cosmos

Weak nuclear force

The 'weak' force is actually the third weakest of the four. It's responsible for the way subatomic particles interact and is the cause of radioactive decay.

Gravitational force

This is a force that attracts objects with mass to each other - it's what keeps the planets in orbit around the Sun. It's the weakest of all four forces.

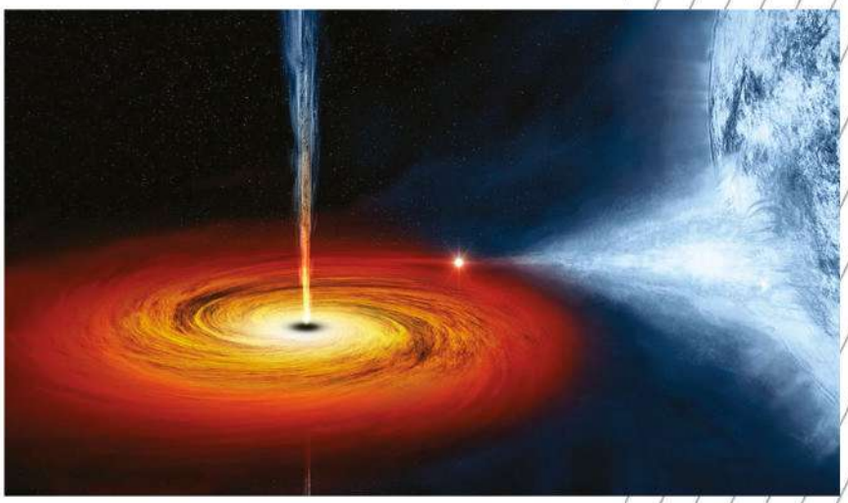


Electromagnetic force

Responsible for the interactions between charged particles, the electromagnetic force includes both electricity and magnetism.

Strong nuclear force

This holds most matter together by binding quarks together into hadrons. It only works at tiny distances, but at these distances it's the strongest force.



The stellar black hole Cygnus X-1 has a magnetic field around it

through something called the Biermann battery," says Widrow. The process, discovered by Ludwig Biermann in 1950, starts out with a plasma made up of electrons and protons. If the plasma is hotter on one side and denser on the top than the bottom, the electrons will start to drift to the colder temperature, lower density side faster than the protons because they have a lower mass and lower inertia. And this movement of charge will create a magnetic flux. "Since the timescale for a star to rotate is very short compared to cosmic timescales, these fields can be rapidly amplified via a stellar dynamo," explains Widrow. The solar activity of our own Sun is an example of a stellar dynamo in action. "If the star then explodes as a supernova, its fields will be expelled into the interstellar medium."

Another option is that the fields were produced in the early population of active galactic nuclei, which were then driven out into the intergalactic medium by active galactic nuclei jets. Yet another possibility is that fields were generated during the earliest stages of galaxy formation. However, when it comes to the question of astrophysics versus cosmology, "we are yet to obtain any data at all that might point towards one culprit over another," says Gaensler. The problem is that it's difficult to gather evidence. "Both cosmological and astrophysical processes could generate initial weak magnetic fields, but we don't know which ones actually operated and which ones ended up contributing to the magnetic fields we see today," says Gaensler.

"Magnetic fields could be produced in the very early universe, during an epoch of inflation"

One of the best ways of searching for magnetic fields is by looking for radio waves. The strength of a magnetic field can be deduced from synchrotron emission – electromagnetic radiation emitted when charged particles are accelerated radially. The polarisation of the radiation can then be used to work out the plane of the magnetic field. The Zeeman effect, the way light splits into different spectra in the presence of a magnetic field, can be used to work out the magnetic field of cold clouds of gas.

The European Space Agency's (ESA) Planck satellite, which orbited Earth from 2009 to 2013, studied the universe at far-infrared, microwave and high-frequency radio frequencies with high sensitivity in order to probe the cosmic microwave background radiation. In January 2017, evidence gathered by Planck revealed gigantic loops of magnetism and other structures that point to a magnetic dynamo at work in the Milky Way. Then, in March 2017, a group of German astronomers used the 100-metre (328-foot) diameter radio telescope at Effelsberg to observe several galaxy

OUR MAGNETIC UNIVERSE

From tiny planets to colossal black holes, a variety of objects across the universe produce magnetic fields

Earth

Strength of magnetic field: 0.25 to 0.65 gauss
Size of magnetic field: 63 kilometres (39 miles) on one side and 130 kilometres (80 miles) on the other
Earth's magnetic field is generated by liquid iron moving around in the outer core. The shape of the field is distorted by the solar wind.

Sagittarius A*

Strength of magnetic field: 202 gauss at the core
Size of magnetic field: 150 light years
Roughly 150 light years from the black hole's core, the field is only one-hundredth the strength of the magnetic field around Earth.

CLASS B1152+199

Strength of magnetic field: Around a few microgauss
Size of magnetic field: Uncertain
In 2017, astronomers found a galaxy nearly 5 billion light years away with a magnetic field of a similar strength to that of the Milky Way.

The Milky Way

Strength of magnetic field: A few microgauss
Size of magnetic field: 6 to 40 microgauss
The average strength of the magnetic field in the Milky Way is about six microgauss near the Sun and increases to 20 to 40 microgauss in the galactic centre.

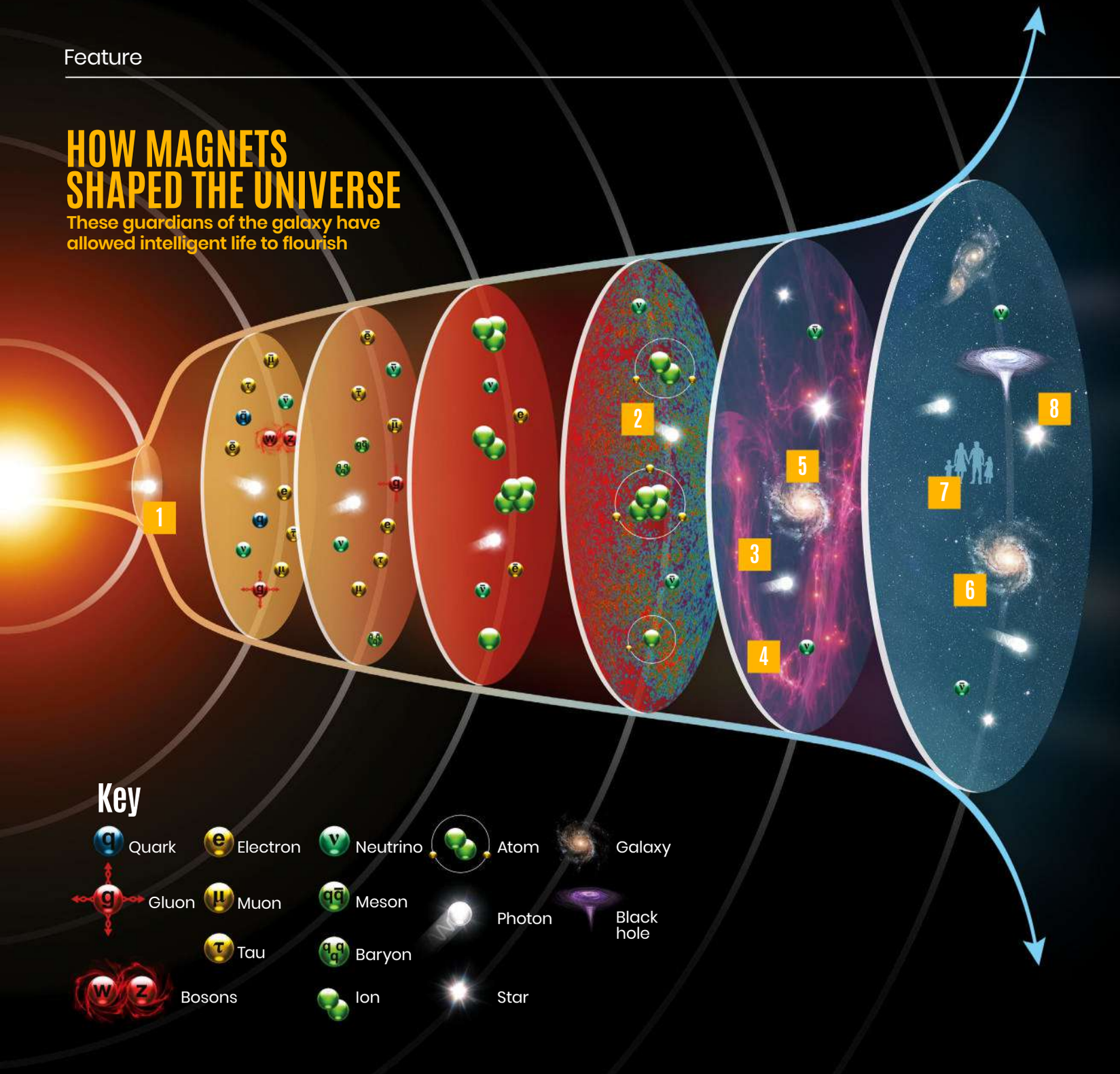
The Sun

Strength of magnetic field: 3,000 gauss on sunspots
Size of magnetic field: The size of the Solar System
The Sun has two magnetic poles – like a huge bar magnet – which create its field. The poles flip at the peak of the solar activity cycle every 11 years.

© NASA; M. Weiss/CfA; Bill Saxton, NRAO/AUI/NSF

HOW MAGNETS SHAPED THE UNIVERSE

These guardians of the galaxy have allowed intelligent life to flourish



Key

- Quark
- Electron
- Neutrino
- Atom
- Galaxy
- Gluon
- Muon
- Meson
- Photon
- Black hole
- Tau
- Baryon
- Bosons
- Ion
- Star

1 Inflation

One theory says that seed magnetic fields could have been produced during the epoch of inflation, when the universe expanded exponentially.

2 The formation of stars

Magnetism is essential for stars to form by preventing clouds of gas from collapsing too much.

3 The early galaxies

We know that 5 billion years ago, galaxies already had magnetic fields as strong as that of our own galaxy.

4 Intergalactic medium

The pressure in the intergalactic medium is partly maintained thanks to the magnetic fields permeating through it.

5 Supernova explosions

When very massive stars explode, they spew out high-energy electrons that emit gamma rays, which are deflected by magnetic fields.

6 Spiral galaxies

Some evidence suggests the arms of spiral galaxies are formed because of magnetic fields.

7 Evolution of life on Earth

Our planet's magnetic field protects us from the harmful cosmic rays that race through space.

8 Formation of planets

The movement of grains of dust around stars like the Sun, which can eventually form planets, are highly influenced by magnetic fields.

clusters. At the edges of these large accumulations of stellar systems, hot gas and charged particles, they found the most extended magnetic fields in the universe known so far. The telescope is still searching for more evidence.

"The Effelsberg radio telescope proved again to be an ideal instrument to detect magnetic fields in the universe," says Rainer Beck, formerly of the Max Planck Institute. "Now we can systematically search for ordered magnetic fields in galaxy clusters using polarised radio waves." The Low-Frequency Array, or LOFAR, is a large network of radio telescopes that's being used to study fields in galaxies that formed early on in the universe, but nothing conclusive has been found yet. "Unfortunately, the only data we have on magnetism in the early universe are upper limits… non-detections," says Gaensler. Once we understand the universe's magnetic field in more detail, it will help us to understand and model other aspects of the universe too. For example, models of how galaxies evolved could benefit from including a value for the magnetic field, even if it has long been ignored. But first we must gain greater insight into its history. This is why more evidence needs to be gathered before conclusions are drawn.

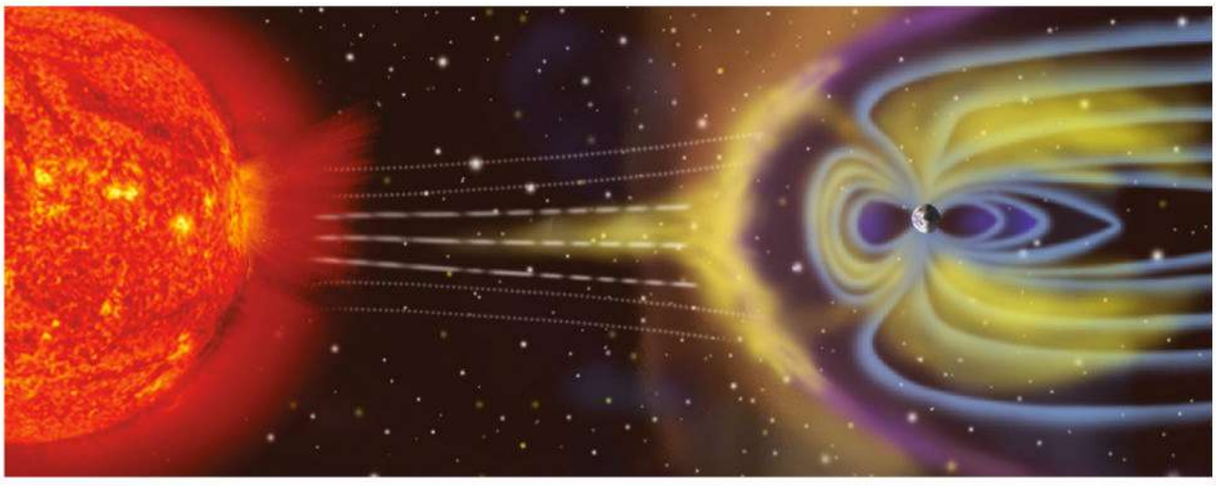
If telescopes can find evidence of strong magnetic fields in protogalaxies, the masses of dust and gas that clump together to form galaxies, it would indicate the magnetic fields were formed during inflation or in early active galactic nuclei. However, if the first fields are found in already-formed galaxies, this could mean the magnetic field originated from early stars. The Square Kilometre Array (SKA) is an international project to build the world's largest radio telescope. Once construction is complete, the telescopes will sit over an area of one square kilometre (0.38 square miles), making it at least five times more sensitive and 60 times quicker than today's best radio telescopes. This should give astronomers completely new insight into the intensity of magnetic fields across the universe.

As part of its observations, SKA will spend a year looking at the Faraday rotation – the interactions between light and a magnetic field – of millions of galaxies beyond our own. Studying the Faraday

rotation of the electromagnetic waves can reveal information about the magnetic field over the plane of the line of sight. This will increase the amount of data by five orders of magnitude over current datasets. "Through the unique sensitivity and resolution of the Square Kilometre Array, the window to the magnetic universe can finally be fully opened," the project website says. Construction of the project began on 5 December 2022 in both South Africa and Australia, and is expected to continue until 2028. Hopefully the experiment will be able to give us the insight needed to make the right measurements to finally understand the origin of this forgotten but vital force, and its place in the universe.

Abigail Beall
Science journalist
Abigail holds a master's degree in physics and a master's in science journalism from City University, London. She is currently a features editor at *New Scientist*.

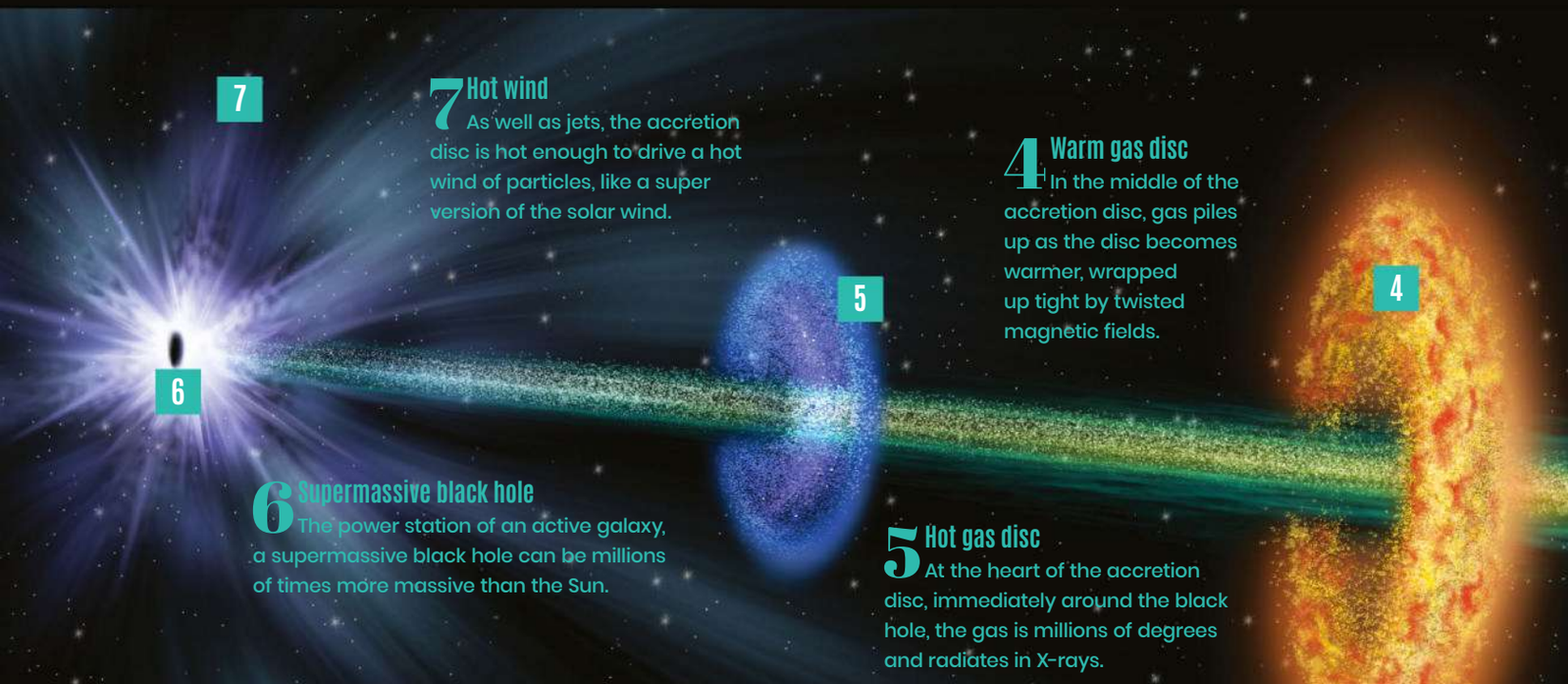
"Once we understand the universe's magnetic field, it will help us to understand other aspects of the universe"



Magnetic field data from the Whirlpool Galaxy (Messier 51)

Magnetic fields could protect life on exoplanets' surfaces

© NASA; Tobias Roetsch; MPIfR Bonn


7
7 Hot wind
As well as jets, the accretion disc is hot enough to drive a hot wind of particles, like a super version of the solar wind.
4 Warm gas disc
In the middle of the accretion disc, gas piles up as the disc becomes warmer, wrapped up tight by twisted magnetic fields.
5
4
6
6 Supermassive black hole
The power station of an active galaxy, a supermassive black hole can be millions of times more massive than the Sun.
5 Hot gas disc
At the heart of the accretion disc, immediately around the black hole, the gas is millions of degrees and radiates in X-rays.

FOCUS ON

A BLACK HOLE SHOT OUT A BRIGHT X-RAY JET 60,000 TIMES HOTTER THAN THE SUN

The recently detected quasar is extremely bright and hot

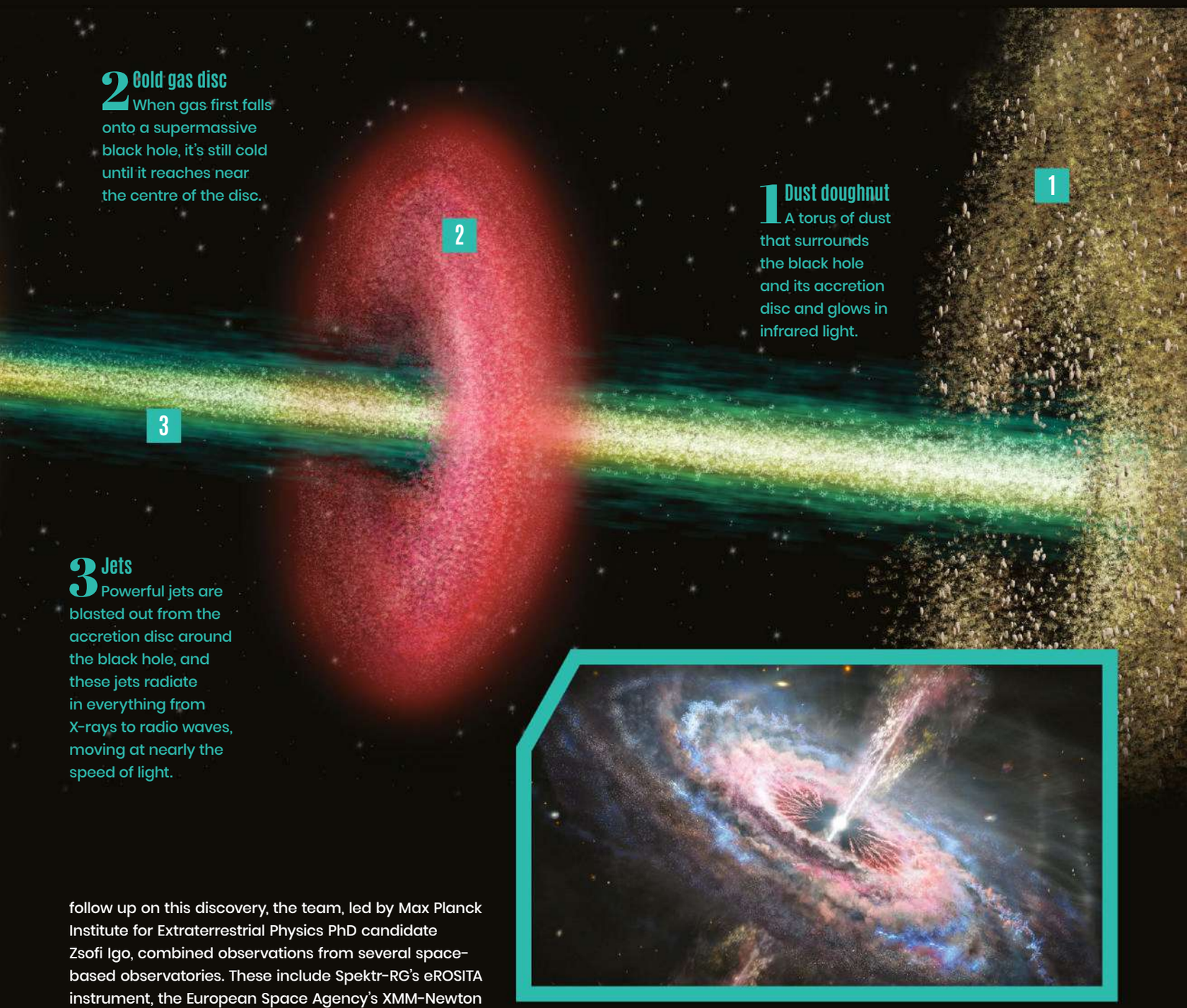
Reported by Robert Lea

Astronomers stared deep into the heart of a hungry black hole, only to discover a jet of X-rays beaming out of it that's 60,000 times hotter than the surface of the Sun. Quasars are black holes with bright energetic jets of electromagnetic radiation beaming out of them from two sides as they feed on cosmic material. The quasar is known as SMSS J114447.77–430859.3 and is the most luminous example of such an object seen in the last 9 billion years of cosmic history. Located at the heart of a galaxy around 9.6 billion light years away from Earth and seen in the sky between the constellations of Centaurus and Hydra, this quasar is around 100,000 billion times brighter than the Sun.

Quasars like J1144 are so bright that they often outshine the combined light of every star in the galaxies that house them. They are examples of so-called active galactic nuclei (AGN) that are found only at vast distances from Earth, and thus in the early universe. Studying the quasar could offer astronomers a detailed insight into these powerful cosmic events and the effect they have on their galactic surroundings.

Scientists theorise that the reason quasars are found in the early universe is that the galaxies just a short time after the Big Bang were richer in gas and dust. This meant they possessed enough fuel to allow their central black holes to power bright emissions across almost the entire electromagnetic spectrum, including low-energy radio, infrared, visible and ultraviolet wavelengths, and high-energy X-ray wavelengths.

J1144 was initially spotted in visible light by the SkyMapper Southern Sky Survey (SMSS) in 2022. To

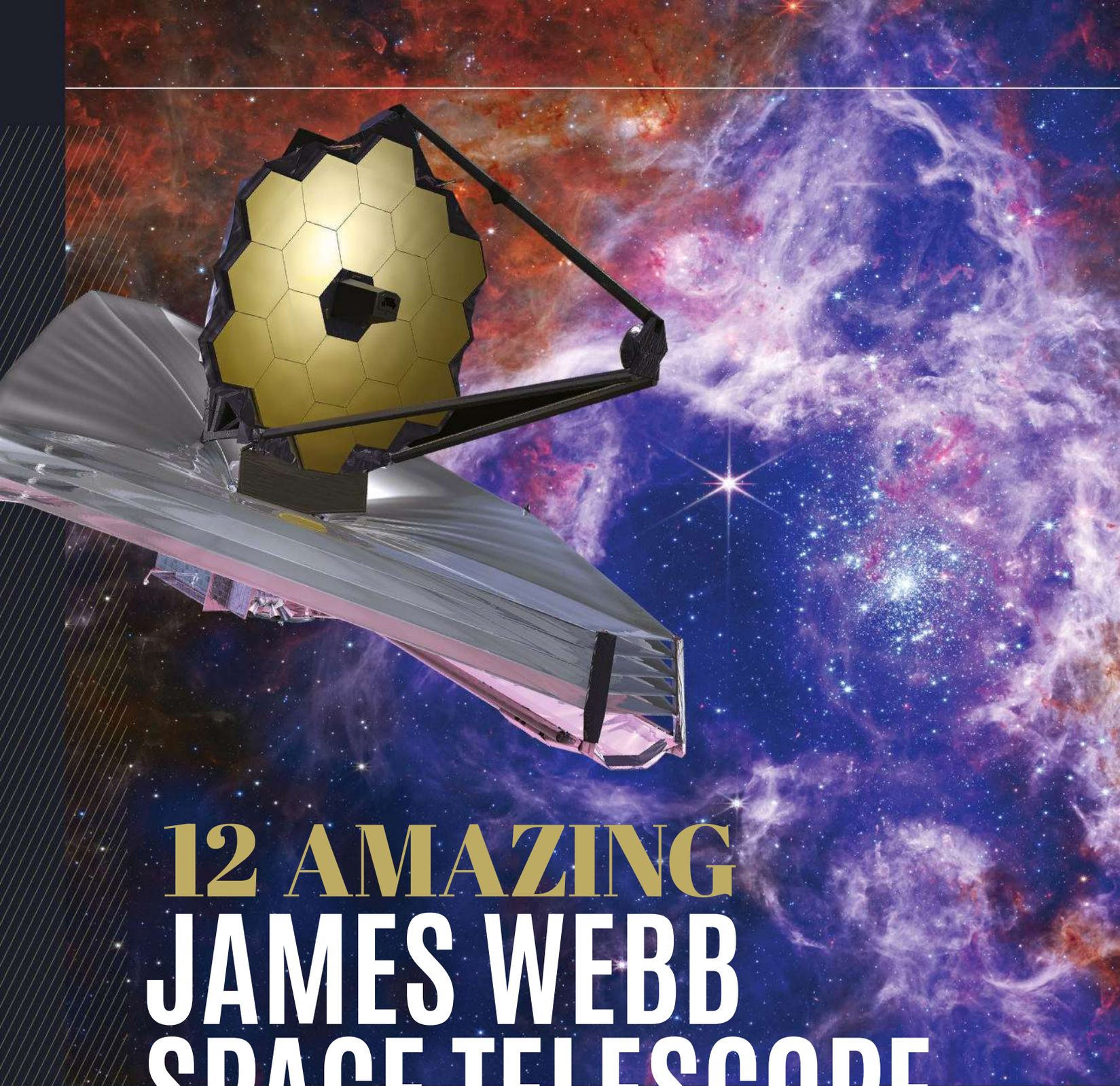

2 Cold gas disc
When gas first falls onto a supermassive black hole, it's still cold until it reaches near the centre of the disc.
1 Dust doughnut
A torus of dust that surrounds the black hole and its accretion disc and glows in infrared light.
3 Jets
Powerful jets are blasted out from the accretion disc around the black hole, and these jets radiate in everything from X-rays to radio waves, moving at nearly the speed of light.
1
2
3

An artist's impression of a quasar

follow up on this discovery, the team, led by Max Planck Institute for Extraterrestrial Physics PhD candidate Zsofi Igo, combined observations from several space-based observatories. These include Spektr-RG's eROSITA instrument, the European Space Agency's XMM-Newton observatory, NASA's Nuclear Spectroscopic Telescope Array and NASA's Neil Gehrels Swift Observatory. This combination of data allowed the astronomers to measure the temperature of the X-rays coming from the quasars, discovering this to be around 350 million degrees Celsius (630 million degrees Fahrenheit). This is a staggering 60,000 times hotter than the temperature at the surface of the Sun.

The team was also able to put a value on the mass of the black hole behind these emissions, finding it to be around 10 billion times that of the Sun. Not only this, but the supermassive black hole of J1144 is feeding so quickly that it is growing at a rate of 100 Suns per year. Not all the gas surrounding this black hole is being fed to it, however. The scientists discovered that some gas is being ejected from the quasar in the form of extremely powerful winds that are injecting vast amounts of energy into its surrounding galaxy. The team also found that J1144 has a characteristic that sets it apart from other quasars: the X-ray light it emits varies on a timescale of just a few Earth days. For a quasar with a black hole this size, the variability of its X-rays would usually be on a timescale of months or even years. "We were very surprised that no prior X-ray observatory has ever observed this source, despite its extreme power," Dr Elias Kammoun of the Research Institute in Astrophysics and Planetology added. "A new monitoring campaign of this source will start, which may reveal more surprises from this unique source."

© NASA



12 AMAZING JAMES WEBB SPACE TELESCOPE BREAKTHROUGHS

Webb is peering across the universe to discover new things about planets, galaxies and other cosmic objects

Written by Rebecca Sohn

"The James Webb Space Telescope is a pathfinder of scientific discovery"

NASA's deep-space observing telescope is looking at the universe like never before. The James Webb Space Telescope is a pathfinder of scientific discovery, generating incredible insights about galaxies, planets, stars and all sorts of interesting cosmic objects. The telescope is near the beginning of its cosmic journey, as it is rated for 20 years of operations and just launched in December 2021. Billed as a successor to the venerable Hubble Space Telescope, Webb is also breaking ground in science excitement.

1 WEBB IS HAILED AS THE GREATEST SPACE BREAKTHROUGH

When Webb launched on 25 December 2021, it was the culmination of decades of work by NASA scientists and engineers. The launch went off without a hitch, as did the numerous steps of the telescope's deployment in the following months. In mid-July Webb released its stunning first images. The infrared telescope will help us see almost every part of our universe in greater detail, including the most distant galaxies, allowing us a glimpse into the past. "Within days of [Webb] coming online in late June 2022, researchers began discovering thousands of new galaxies more distant and ancient than any previously documented – some perhaps more than 150 million years older than the oldest identified by Hubble," editors of the journal *Science* said. The journal named Webb as its Science Breakthrough of 2022, while the journal *Nature* chose Jane Rigby, Webb's operations project scientist, to include in their 'ten people who helped shape science stories' list for 2022.

"What's more, the telescope is capable of collecting enough light from astronomical objects – ranging from birthing stars to exoplanets – to reveal what they are made of and how they are moving through space," the editors of *Science* said. "This data has already begun to reveal the atmospheric composition of planets hundreds of light years from Earth in great detail, offering hints as to their ability to potentially support life as we know it."

Webb is a worthy successor to Hubble, spying further into the universe

© NASA-ESA

2 STARS BORN IN THE PILLARS OF CREATION

The Pillars of Creation in the Eagle Nebula have long been one of the Hubble Space Telescope's most iconic images. But though the telescope, which detects mostly visible light, captured the structure's impressive clouds, the 'creation' happening within them was hidden. Now, Webb's infrared imaging has managed to capture it in the form of numerous protostars. Appearing as tiny red dots against the smoky backdrop of the pillars, these collections of dust and gas, each many times larger than our Solar System, are stars being born.

"These young stars that we see in the image are not yet burning hydrogen," Derek Ward-Thompson, head of the school of natural sciences at the University of Central Lancashire in the UK, said. "But gradually, as more and more material falls in, the middle becomes denser and denser, and then suddenly it becomes so dense that the hydrogen burning switches on, and then suddenly their temperature jumps up to about 2 million degrees Celsius [3.5 million degrees Fahrenheit]." The image was created using different colours to represent mostly invisible infrared wavelengths, said Anton Koekemoer, a research astronomer at the Space Telescope Science Institute in Baltimore, who put the image together using Webb data.

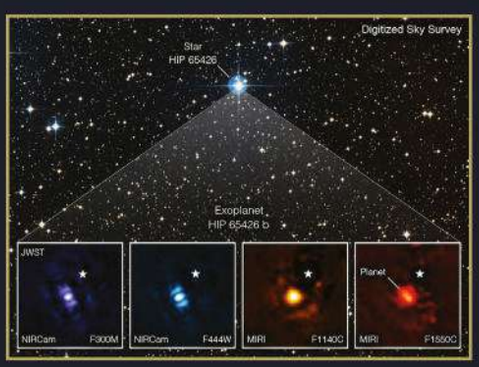
▲ The Pillars of Creation are iconic in astronomy

▶ HIP 65426 b was once known as Najsakopajk

3 WEBB'S FIRST DIRECT IMAGE OF AN EXOPLANET

Scientists discovered the first exoplanets in the 1990s, and today there are over 3,000 known worlds orbiting faraway stars. Still, only around two dozen of these have been imaged directly. Most exoplanets are so far away that they can only be detected through a dip in the light of the star they're orbiting when that planet passes in front of its host star. But Webb could change that. In September 2022, it captured its first direct image of an exoplanet. "This is a transformative moment, not only for Webb but also for astronomy generally," Sasha Hinkley, an astronomer at the University of Exeter in the UK who led these observations, said.

The planet, called HIP 65426 b, was discovered in 2017. To view it, scientists used two of Webb's cameras, several filters and the telescope's coronagraphs – tools which block out the light of the central star. Along with the telescope's exceptional sensitivity, the planet has several features that make it easier to observe. At 100 times the distance from our Sun to Earth, this planet is much farther away from its host star than any planet in our Solar System – in contrast, Pluto is only 40 times that Sun-Earth distance. A colossal gas giant, it's also exceptionally large – about 12 times the size of Jupiter.



"These young stars that we see in the image are not yet burning hydrogen"

Derek Ward-Thompson

4 RE-IMAGING THE PHANTOM GALAXY

Though the Phantom Galaxy is difficult to find in the night sky, its brilliance is far from invisible, especially when captured in infrared. Hubble's optical image of the galaxy shows the galaxy's perfect spiral structure and its distribution of stars, in arms extending outwards from a radiant centre. But a new Webb image reveals fibre-like structures of heat-emitting dust and gas emanating from a bright centre rendered in vivid electric blue. The image will shed light on star-forming regions scattered in the galaxy's spiral arms. A mesmerising composite image combining the Hubble Space Telescope and Webb images features aspects of both optical and infrared observations of the galaxy.

5 MYSTERIOUS BOXY RIPPLES EXIST AROUND A WOLF-RAYET STAR

In July 2022, Webb captured an image of a distant star that featured Webb's signature diffraction pattern. But around the star, called WR 140, is a pattern that looks equally unreal – a ripple-like pattern of concentric rings that have a peculiar, slightly boxy shape. Unlike the diffraction pattern, the unlikely shaped rings are real features. "The six-pointed blue structure is an artefact due to optical diffraction from the bright star WR 140 in this JWST MIRI image," wrote Mark McCaughrean, an interdisciplinary scientist in the James Webb Space Telescope science working group and a science advisor to the European Space Agency, in a twitter thread. "But the red curvy-yet-boxy stuff is real, a series of shells around WR 140. Actually in space. Around a star."

Wolf-Rayet stars are massive stars near the end of their lives, already having released much of their hydrogen. The strangely shaped rings are caused by the interaction between WR 140 and its smaller companion star. The stars are surrounded by a cloud of dust that is sculpted into that shape by its companion star, said McCaughrean. Ryan Lau, an astronomer at NOIRlab in Arizona, led the team studying these observations as part of the JWST Early Release Science program. In October, the team published a study on the observations in the journal *Nature Astronomy.*

▲ The Phantom Galaxy is also called Messier 74

▲ Wolf-Rayet stars are rather rare

© NASA; ESA

"These [galaxies] are well beyond what we could have imagined finding before Webb"

Brant Robertson

6 FINDING THE MOST DISTANT GALAXIES EVER

Webb was made to observe the most distant galaxies in the universe, and in mid-December 2022, scientists confirmed that they had done just that. The telescope has officially observed the four most distant galaxies known, which also means they are the oldest. Webb observed the galaxies as they appeared about 13.4 billion years ago, when the universe was only 350 million years old, about two per cent of its current age.

Scientists suspected that the four galaxies were incredibly ancient, like hundreds of others identified by Webb. As part of the JWST Advanced Deep Extragalactic Survey (JADES), researchers confirmed their age, analysing data from the telescope's Near Infrared Spectrograph to find out how fast the galaxies were moving away from the telescope. This is the galaxies' redshift – how much the wavelengths of light they shed have lengthened as the universe expands. Their redshift was 13.2, the highest ever measured. "These [galaxies] are well beyond what we could have imagined finding before Webb," Brant Robertson, an astrophysicist at the University California, Santa Cruz, and one of the researchers involved in the observations, said. "With Webb, for the first time we can now find such distant galaxies and then confirm spectroscopically that they really are that far away."

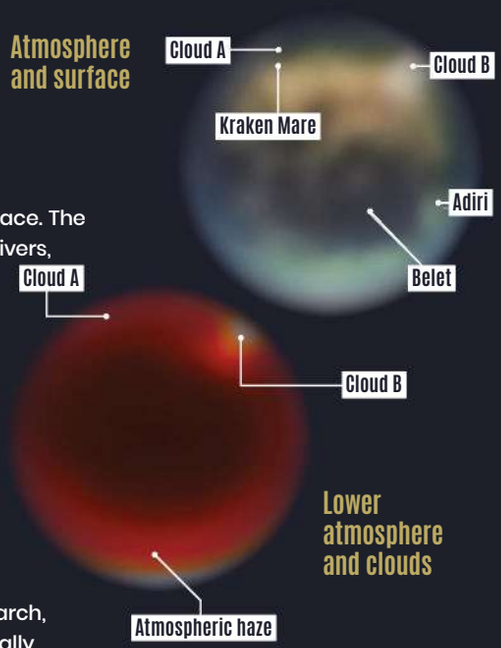
Webb can peer back into the ancient universe with its high-tech infrared instruments

WASP-39 b is classified as a 'hot Jupiter'

7 LOOKING AT AN EXOPLANET'S ATMOSPHERE IN DETAIL

Thanks to Webb, a planet orbiting a star in the constellation of Virgo is now the most explored world outside our Solar System. The planet is called WASP-39 b and is about 700 light years from Earth. It's a boiling gas giant about the size of Saturn, orbiting its host star at an absurdly close distance – about eight times closer to its host star than the planet Mercury is to our Sun. Using Webb's main camera and two of its spectrographs, scientists identified carbon dioxide in its atmosphere – the first time the gas has ever been found in an exoplanet's atmosphere – though the planet's bulky atmosphere is dominated by thick clouds containing sulphur and silicates, including sulphur dioxide.

8 GLIMPSING TITAN'S CLOUDS



Saturn's moon Titan is a weird and intriguing place. The moon has 'rock' made of water ice, as well as rivers, lakes and seas made of liquid methane and ethane. It's also the only moon in our Solar System to have a thick atmosphere – a hazy one dotted with methane clouds. Scientists got a glimpse of some of those clouds in November 2022, when Webb captured atmospheric data from the weird moon.

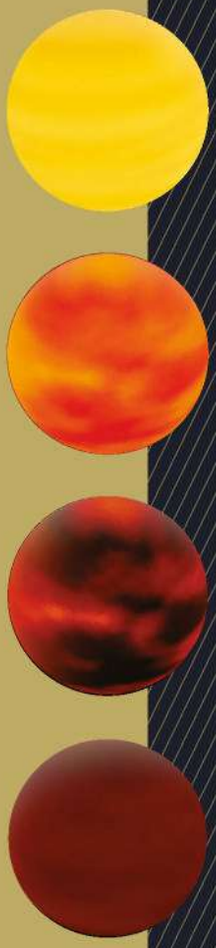
Researchers studying Titan with Webb expressed their excitement on receiving the data. "At first glance, it's simply extraordinary," Sébastien Rodriguez, an astronomer at the Université Paris Cité and colleague on the research, said. "I think we're seeing a cloud!" They eventually found that the telescope captured not one but two clouds, including one over the moon's largest sea, Kraken Mare. The team was so intrigued that they contacted Keck Observatory in Hawaii, which was able to observe Titan just two days later. In the Keck observations there's a cloud over Kraken Mare in the same place, though it's a different shape, indicating that the cloud either changed or another cloud moved into the same spot.

9 THE SECRETS OF THE SOUTHERN RING NEBULA

Scientists always thought of the Southern Ring Nebula as rather unremarkable. The thinking went that the nebula was simply a dying star, called a white dwarf, that had expelled its outer layers, which glow brightly as the white dwarf radiates waves of energy. Scientists also knew that another non-dying star, part of a binary system, was largely obscured beneath the brightly lit gas. But Webb's stunning image of the nebula, released as part of its first images and data, made it clear that it wasn't that simple. Webb imaged the cloud with two of its instruments, the Near Infrared Camera (NIRCam) and the Mid-Infrared Instrument (MIRI). With MIRI, researchers saw that the white dwarf wasn't invisible, as they'd expected in that wavelength, but glowing red, surrounded by a haze of cool gas. Where did the gas come from? The only logical explanation, it seemed, was that the nebula hid a third star, which was the source of the gas. The telescope's main camera also captured intriguing shells around the outer edges of the nebula, somewhat like those around WR 140. They think a third star, somewhere between the two known ones, could have caused the ripple-like shells.

NGC 3132, the Southern Ring Nebula, is in the constellation of Vela

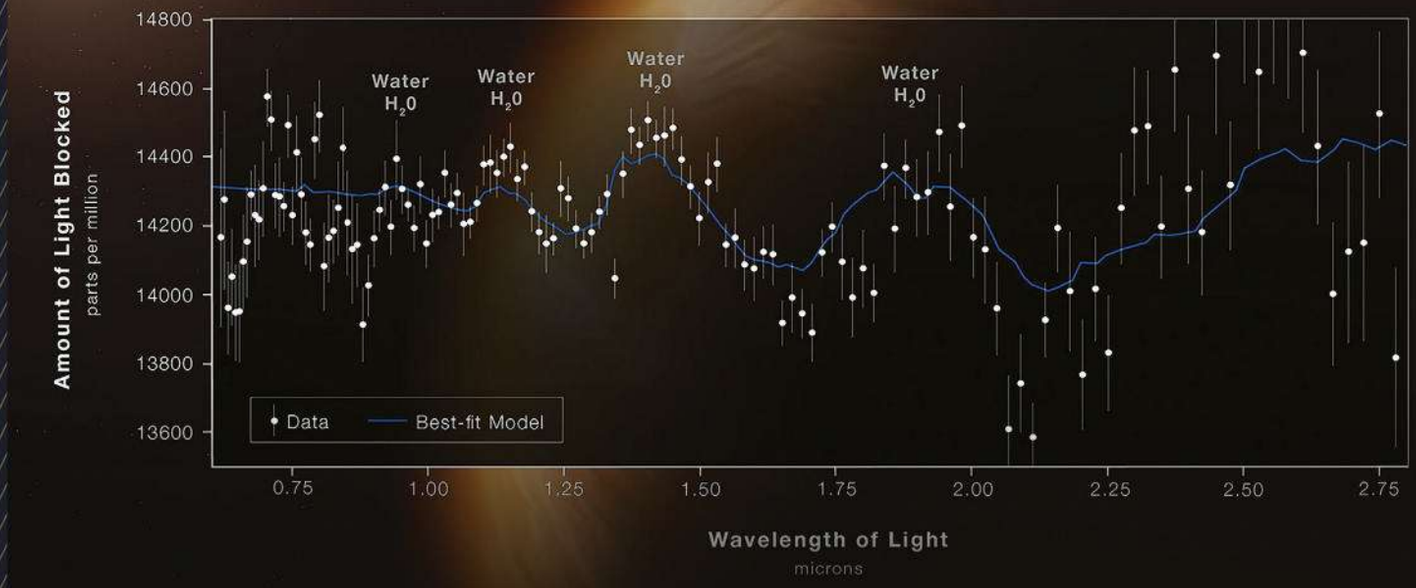
10 WEBB DISCOVERS A BROWN DWARF WITH SAND CLOUDS



Though many telescopes have identified exoplanets, Webb wasn't designed to. But discover one it did – and it's an exceptionally weird one. For one, VHS 1256 b isn't a planet at all. It's a brown dwarf – bigger than a planet, but too small to be a proper star. This one gives off a dim, reddish glow, a product of the modified form of fusion that happens on objects that are very massive, but are too small to fuse hydrogen. Stranger still, Webb observed that the brown dwarf has sandy silicate clouds – a first for this kind of object. The exoplanet is also small for a brown dwarf, and therefore young.

As with WASP-39 b, Webb was able to identify individual chemicals in the brown dwarf's strange atmosphere, such as water, methane, carbon dioxide and potassium, among others. Ratios of the different compounds suggest that the object has a turbulent atmosphere. "In a calm atmosphere, there's an expected ratio of, say, methane and carbon monoxide," Sasha Hinkley, an astronomer at the University of Exeter in the UK and one of the study's co-authors, said. "But in many exoplanet atmospheres we're finding that this ratio is very skewed, suggesting that there is turbulent vertical mixing in these atmospheres, dredging up carbon dioxide from deep down to mix with the methane higher up in the atmosphere."

© NASA; ESA



11 NOT-SO-CLOUDLESS PLANET

As part of its first release of Webb data, NASA released the telescope's first spectrum of the atmosphere of an exoplanet, from a planet called WASP-96 b. Webb's spectrographs analysed the light of the planet's star filtered through the planet's atmosphere as it crossed in front, obtaining a spectrum, a kind of 'barcode' of the wavelengths of light absorbed by the planet's atmosphere. The spectrum detected signs of hazy skies, clouds and water vapour on the planet. This is strange, considering that scientists previously thought the planet didn't have any clouds at all.

The planet's atmosphere has a strong sodium signature, something that researchers thought until recently meant it had unique, entirely cloudless skies. The results are so contradictory that scientists are reanalysing the Webb and previous data, trying to figure out how to reconcile the seemingly opposite conclusions.

The signs of water on the distant planet almost definitely don't indicate that it could have life. The planet is a 'hot Jupiter' – a gas giant half as massive but slightly larger than our Solar System's largest planet. It's very close to its host star, orbiting it every 3.4 days.

- WASP-96 b is unlike any planet in the Solar System
- Webb unveiled intense star formation in colliding galaxies

12 HIDDEN STAR FORMATION AS GALAXIES COLLIDE

One of Webb's strengths as an infrared telescope is its ability to peer through dust, revealing things hidden from telescopes like Hubble, which use mostly visible light. When Webb captured an image of two galaxies colliding, it saw something Hubble had missed – an area of intense star formation, which scientists say is producing stars 20 times faster than in our own galaxy. In the new image, the merging galaxies, called IC 1623, contain an area of star formation that shines so bright with infrared radiation that it produces Webb's typical pointed-star diffraction pattern, which is usually the result of its observing bright stars. The area makes up a completely new layer of the image, hidden from Hubble.

© NASA; ESA

FEED YOUR MIND

www.howitworksdaily.com

AMAZING FACTS
COOLEST TECH
WHERE DOES YOUR POO GO?
HOW IT WORKS
BODYCAMS, TASERS AND SMART POLICE CARS
WHY WE NEED FLIES
LIVING ON THE MOON
WHAT IF THERE WAS NO GRAVITY?
GIANT ROAD-PAVING MACHINE
WHY RAIN SMELLS
ANIMAL PREGNANCIES
INSIDE A CLASSIC F1 RACE CAR
HOW THIS FUNDAMENTAL FORCE BINDS YOU TO THE UNIVERSE AND EVERYTHING IN IT
HOW CARS ARE RECYCLED
SCIENCE TECH ENVIRONMENT SPACE HISTORY
SCIENCE UP CLOSE
ILLUSTRATIONS
INSIDE GADGETS

BUY YOUR ISSUE TODAY!

HOW IT WORKS™

Print and digital subscriptions available at www.magazinesdirect.com

Also available from all good newsagents and supermarkets

How It Works magazine | @HowItWorksmag | howitworks@futurenet.com | howitworksmag

FOCUS ON

A STRANGE STAR SYSTEM MAY HOLD THE FIRST EVIDENCE OF AN ULTRA-RARE 'DARK MATTER STAR'

A Sun-like star has been found to orbit an invisible object that may be the first example of a 'boson star'

Reported by Paul Sutter

Astronomers long thought that a peculiar star system observed by the European Space Agency's Gaia satellite was a simple case of a star orbiting a black hole. But two astronomers are challenging that claim, finding that the evidence suggests something far stranger: a never-before-seen type of star made of invisible dark matter. The system consists of a Sun-like star, and something else. The star weighs 0.93 solar masses and has roughly the same chemical abundance as the Sun. Its mysterious companion is much more massive – around 11 solar masses. The objects orbit each other at a distance of 1.4 astronomical units, about the distance at which Mars orbits the Sun, making a complete orbit every 188 days.

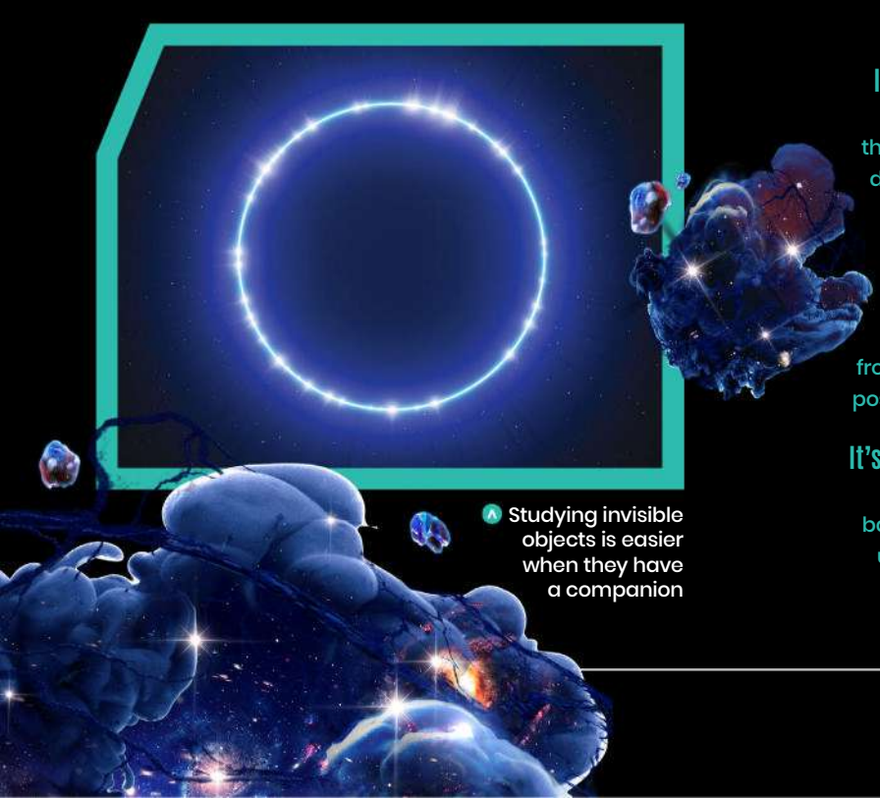
What could that dark companion be? One possibility is that it's a black hole. While that would easily fit the bill in terms of the orbital observations, that hypothesis has challenges. Black holes form from the deaths of very massive stars, and for this situation to arise, a Sun-like star would have to form beside one of those monsters. While not outright impossible, that scenario requires an extraordinary amount of fine-tuning to make the match happen and keep these objects in orbit around each other for millions of years. Perhaps that dark orbital companion is something much more exotic, as researchers propose in a new study. Maybe, they suggest, it's a clump of dark matter particles.

Dark matter is an invisible form of matter that makes up the vast majority of the mass of every single galaxy. We still don't have a solid understanding of its identity. Most theoretical models assume that dark matter is smoothly distributed in each galaxy, but there are models that allow it to clump up on itself.

One of these models hypothesises that dark matter is a new kind of boson. Bosons are the particles that carry the forces of nature – for example, a photon is a boson that carries the electromagnetic force. While we know of only a limited set of bosons in the Standard Model of particle physics, there's nothing stopping the universe from having many more kinds. These kinds of bosons wouldn't carry forces, but they would still soak the universe. Most importantly, they would have the ability to form large clumps. Some of these clumps could be the size of entire star systems, but some could be much smaller. The smallest clumps of bosonic dark matter could be as small as stars, and these hypothetical objects get a new name: boson stars.

Boson stars would be entirely invisible. Because dark matter doesn't interact with other particles or with light, we could detect them only through the gravitational influence on their surroundings – like if a regular star were to orbit a boson star. The researchers pointed out that a simple model of boson dark matter could produce enough boson stars to make this result in the Gaia data plausible, and that replacing a putative black hole with a boson star could explain all of the observational data.

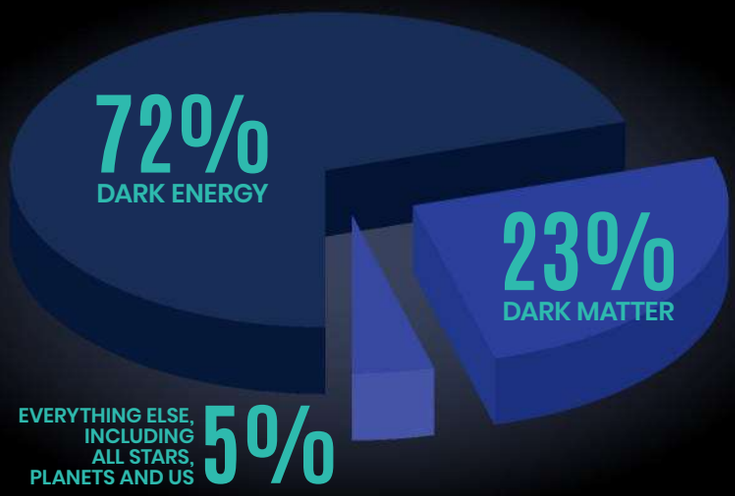
While it's unlikely that this is actually the discovery of a boson star, the authors still urged follow-up observations. Most importantly, this unique system gives us a rare opportunity to study the behaviour of strong gravity, allowing us to examine Einstein's theory of general relativity to see if it holds up. Secondly, if it is a boson star, this system is the perfect experimental set-up. We can play around with our models of boson stars, see how well they can explain the orbital dynamics of this system and use that information to glimpse into the dark corners of the universe.



A Studying invisible objects is easier when they have a companion

DARK MATTER VS DARK ENERGY

Even more mysterious than dark matter is a phenomenon in the universe called dark energy



DARK MATTER

Invisible matter
Scientists think that dark matter may be like ordinary matter, only invisible and non-interacting. But we don't know for sure.

It has a gravitational effect
Matter's dark counterpart has a gravitationally attractive effect on its surroundings. This can be seen in gravitational lensing.

It was seen in the 19th century
Lord Kelvin concluded in 1884 that a large number of 'unseen dark bodies' were present and causing gravitational effects.

Disproved by Voyager 1
The probe would have been able to detect faint radiation from super-small black holes, a possible dark matter candidate.

It's visible in the Big Bang's echo
The cosmic microwave background can show how the universe's web of dark matter evolved over time.

DARK ENERGY

It's speeding things up
5 billion years ago, the expansion of the universe started accelerating. The cause is labelled 'dark energy'.

It's most of the universe
According to data, dark energy comprises an astonishing 72 per cent of the energy density of the entire universe.

Einstein proven right
Einstein found the universe was expanding. He introduced the cosmological constant to fix this, but it may explain dark energy.

Or wrong
From calculations, the cosmological constant is 120 orders of magnitude too large to explain observations.

We're trying to solve the mystery
The Dark Energy Survey is just one of many projects trying to uncover dark energy's secrets.

© Getty

WHAT'S THE STRANGEST THING SENT INTO SPACE?

From LEGO to pizza, this list of space oddities proves that almost anything can make its way into the cosmos

Written by Lee Cavendish

Space exploration is relentless. There's a constant stream of satellites, astronauts and spacecraft waiting to be jettisoned beyond the confines of Earth. Since exploration began in the 1960s, some intriguing and amusing items have found their way up there. Whether they had a legitimate reason or were launched just for some good-natured fun, there have been some strange items sent into space. **All About Space** takes a look back through the years and brings to memory some of the more unusual cosmic visitors – and with the evolution of commercial spaceflight, who knows what weird things will be sent there next!

ALBERT IN SPACE
There were six different monkeys called Albert who made the journey into space.

Ham was trained to pull on levers during spaceflight in response to flashing lights

Schirra and Stafford snuck their instruments onto Gemini 6

OTHER CREATURES OF EARTH

Sadly, during the earliest stages of space exploration, many animals were used for the testing of spaceflights, in part to see its effects on living things. In recent times no such animals have been harmed in the development of space exploration, but these wonderful animals helped us get to where we are now.

Different animals have been sent into space in order to understand the impact of microgravity on the body, but there are a few names that stick out. The first that springs to mind is Laika, the Soviet space dog, whisked from the streets of Moscow, Russia, to become the first animal to orbit Earth with the launch of Sputnik 2 in 1957. Unfortunately Laika did not survive the spaceflight.

Ham is another well-known animal astronaut – the first chimpanzee to be launched into space by the United States in 1961, three months before Alan Shepard's flight. Ham was also trained to perform tasks during the spaceflight. His flight was only 16 minutes and 39 seconds long, with his vital signs monitored while performing simple tasks before he returned back to Earth, suffering only a bruised nose. There are many other animals that paved the way for human exploration, and it's vital not to forget their efforts.

MUSICAL INSTRUMENTS

When humans made the journey into space, it wasn't long before music followed. The first instance was a Christmas-themed prank aboard NASA's Gemini 6, when command pilot Wally Schirra and pilot Thomas Stafford made the first manned rendezvous with Gemini 7.

On 16 December 1965, Schirra went on his radio to report: "We have an object, looks like a satellite going from north to south, probably in polar orbit. Looks like he might be going to re-enter soon. You just might let me pick up that thing. I see a command module and eight smaller modules in front. The pilot of the command module is wearing a red suit."

Only afterwards did he start playing *Jingle Bells* using his tiny four-hole, eight-note Little Lady model harmonica, with Stafford playing five small bells. This was a prearranged prank between Schirra and Stafford, and also the first record of musical instruments played in space. The instruments are now on display at the Smithsonian National Air and Space Museum in Washington DC.

VOYAGER'S GOLDEN RECORDS

In the 1970s, famous American astronomer and science communicator Carl Sagan carried a lot of weight in the construction and implementation of deep-space exploration missions. Sagan also held the view that if these spacecraft were to be picked up along the way by an extraterrestrial intelligent life form, how would they know it was from Earth? This line of questioning is what led to the famous Voyager Golden Records.

NASA's Voyager 1 and 2 spacecraft were launched in 1977, only 16 days apart, and they sent back remarkable images of our Solar System and showed us things we'd never seen before. But aliens may have the same reaction if they come across one of the Voyager spacecraft, so Sagan and his committee created a golden record in an aluminium jacket with instructions on how to play it.

If they were to be picked up and played by aliens, the records both include 115 images in analogue form, greetings spoken in 55 languages, followed by the 'sounds of Earth', and a 90-minute selection of music throughout the ages from around the world.

© NASA; Thinkstock; seewhatmitchsee / Alamy Stock Photo

SPACE BURIALS

Space could kill anyone who ventures there. But who would have thought once someone dies they'd want to be sent there? That's been the case with a few people over the years in the form of their ashes. This may seem peculiar, but it has been the last wish of certain people who have had a strong affinity with the night sky and space. The first was in 1992 with *Star Trek* creator Gene Roddenberry. His will requested that his remains boldly go where no one has gone before, and a portion of his ashes were launched with the Space Shuttle Columbia for the STS-52 mission.

Another famous example is Clyde Tombaugh, the American astronomer who discovered Pluto in 1930. NASA's New Horizons mission was shot at insanely high speeds towards the distant dwarf planet and former ninth planet of the Solar System, and on board the spacecraft were the ashes of Tombaugh. Tombaugh passed away nine years before the launch of New Horizons in 2006, but a portion of his ashes were placed on the spacecraft as per the request written in his will.

^ New Horizons, carrying Clyde Tombaugh's ashes, left Earth on 19 January 2006

© NASA; SpaceX; JHUAP; LEGO; Heritage Images / Getty; Martin Lee / Alamy Stock Photo

PIZZA DELIVERY

It's Friday night, cooking isn't on the agenda and a pizza delivery seems to be the most tempting option for delivery. So you ring up your local pizzeria, order your favourite pizza and wait half an hour for the eagerly anticipated knock at the door. In 2001 a similar routine was conducted in space, as Pizza Hut became the first company to make a delivery beyond the confines of Earth.

Through an odd turn of events, Pizza Hut struck a deal with Russian space agency Roscosmos – reportedly worth £700,000 ($1 million) – to have a pizza delivered to the International Space Station. Russian cosmonaut Yuri Usachov was the lucky recipient and enjoyed some Earth comforts as he posed for the camera with a big thumbs up.

This pizza was tweaked slightly to undergo this unusual delivery. Salami was used instead of pepperoni, as pepperoni didn't withstand the 60-day testing process, and extra salt and spices were used in order to tingle the taste buds, which are depleted in microgravity.

^ Pizzas aren't convenient for spaceflight, but they are delicious

v R2-D2 and NASA astronaut Jim F. Reilly posed with the lightsaber prior to the 14-day STS-120 mission

LUKE SKYWALKER'S LIGHTSABER

Star Wars has inspired generations of science-fiction fans and is still present and popular today. This series of space adventures, where the heroes travel at light speed and visit endless worlds, has inspired many into the real world of astronomy and space exploration.

In 2007, as the International Space Station was being built by a series of Space Shuttle missions, the lightsaber that was used by Mark Hamill in the 1983 film *Episode VI: Return of the Jedi* was flown into space and back. This was to celebrate the 30th anniversary of George Lucas' incredible franchise while a team of seven astronauts were jettisoned into space to deliver and assemble the Harmony module, also known as Node 2.

Prior to launch, an official ceremony was conducted at Oakland International Airport in California, where Chewbacca handed over the memorabilia to NASA officials. It was then sent to Houston, Texas, where it was greeted by Stormtroopers to guide it the rest of the way.

FIRST INTERSTELLAR ADVERTISEMENT
Doritos beamed the first interstellar advertisement in 2008 to a system 42 light years away in the constellation of Ursa Major.

LEGO FIGURINES

Sending LEGO into space wasn't so much a public relations stunt as it was an effort to get children interested in space exploration, in particular the spacecraft that was going to help humanity understand the largest planet in the Solar System, Jupiter. NASA's Juno spacecraft was launched on 5 August 2011, and along with a well-tuned instrumental suite capable of probing the enormous gas giant, there were also three LEGO Minifigures on board. These were the Roman god Jupiter; the spacecraft's namesake, Jupiter's wife Juno and Galileo Galilei, who made several important discoveries about Jupiter. This trio was placed on the Juno spacecraft as part of the Bricks in Space project, an outreach program between LEGO and NASA to inspire children into STEAM-related subjects.

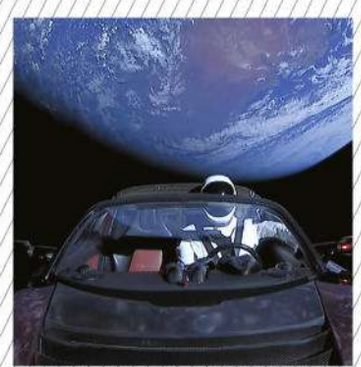
"NASA has a long-standing partnership with the LEGO company," said Scott Bolton, principal investigator for the Juno mission and space science and engineering director at the Southwestern Research Institute in San Antonio, Texas. "Any of you that have children know that LEGO is very popular with kids, as well as really helping to teach them about building and engineering."

< Each figurine was specially made for the Juno mission

TO INFINITY AND BEYOND!
Buzz Lightyear, the iconic character from Pixar's *Toy Story*, made a trip into space aboard the Discovery mission STS-124 in 2008.

STARMAN HEADING FOR THE STARS

More recently, SpaceX performed an extravagant launch of the Tesla Roadster and Starman – SpaceX's spacesuit-clad mannequin driver. Both Tesla and SpaceX are owned by Elon Musk, and he and his team thought that this car delivery would be an appropriate way to commemorate the maiden launch of the Falcon Heavy rocket in February 2018. The test flight had its ups and downs in that the outer cores successfully landed, but the rocket's central core missed its drone ship. However, it was the launch of Starman and the cherry-red Tesla that caught the public's attention.



> SpaceX's Falcon Heavy will launch more than cars when it's fully operational

SNEAKY SANDWICH
Astronaut John Young snuck a corned beef sandwich aboard the Gemini 3 mission.

FOCUS ON

ICE CLOUDS HIGH IN EARTH'S ATMOSPHERE COULD HELP PREDICT CLIMATE CHANGE

A new mission will help us understand how these features respond to climate change and how they might influence our climate in the future

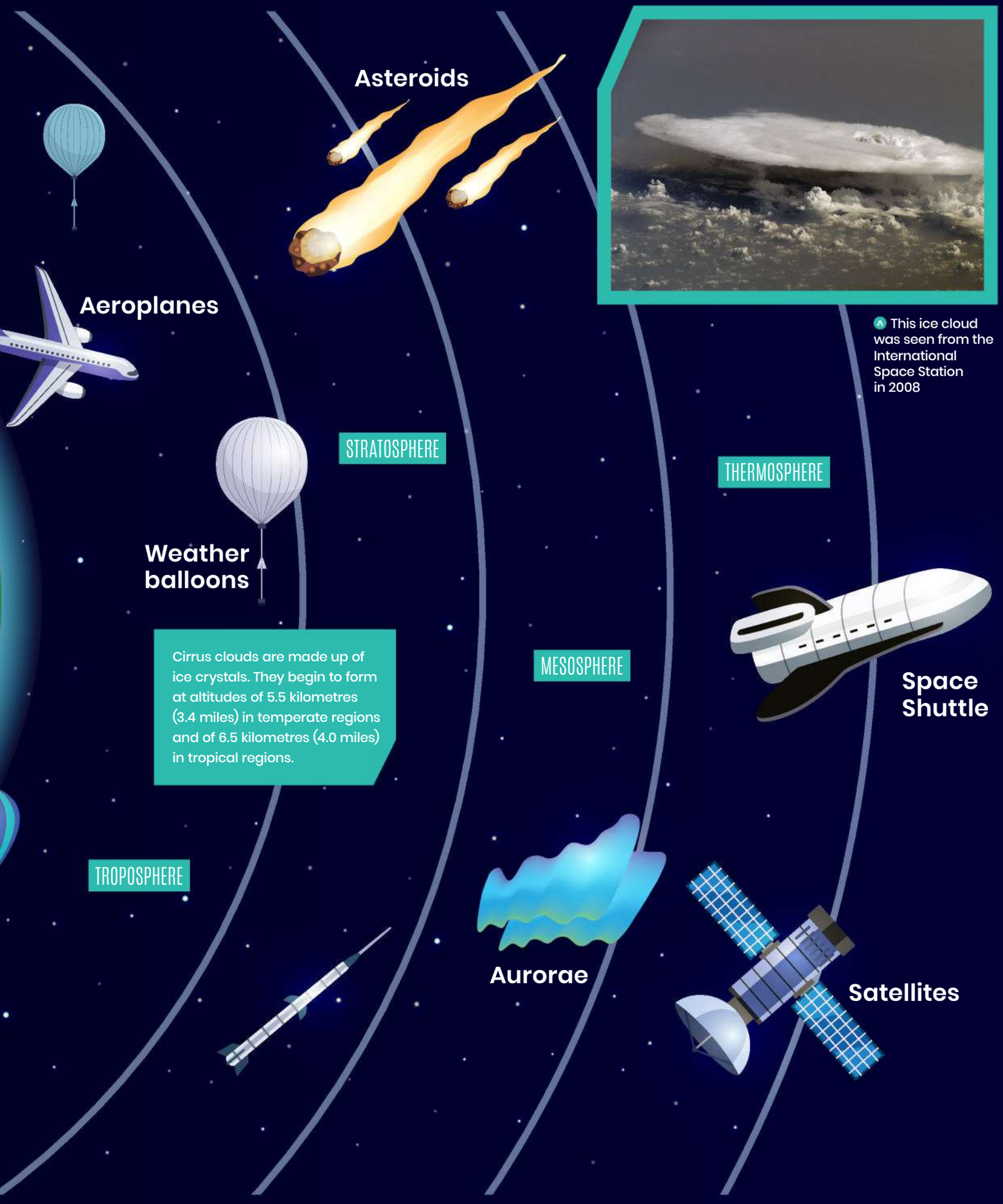
Reported by Rebecca Sohn

An upcoming NASA mission will provide an unprecedented look at ice clouds at high altitudes in Earth's atmosphere. NASA's Polarized Submillimeter Ice-cloud Radiometer (PolSIR) is an instrument designed to study ice clouds that form high above tropical and subtropical regions of Earth. A pair of these relatively low-cost sensors will be mounted on two small satellites and launched into low-Earth orbit, where they will collect data on how ice clouds change over the course of a day. The data will help scientists better understand both how these ice clouds are responding to climate change and how they might influence our climate in the future.

"Studying ice clouds is crucial for improving climate forecasts, and this will be the first time we can study ice clouds in this level of detail," Nicola Fox, associate administrator for the Science Mission Directorate at NASA, said. The equipment for the mission is two identical pairs of radiometers, which will measure electromagnetic radiation coming off the clouds. The radiometers will record infrared radiation at two different frequencies: 325 and 680 gigahertz. Each pair of radiometers will travel aboard a cubesat – a mini satellite a little over 30 centimetres (one foot) tall. The two cubesats will orbit between three and nine hours apart, enabling them to continuously collect data on the ice clouds over a 24-hour period. "The radiometers, which measure the radiant energy emitted by clouds, will significantly improve our understanding of how ice clouds change and respond throughout the day," Karen St. Germain, who leads NASA's Earth Sciences Division, said.

PolSIR is part of NASA's Earth Venture class of missions, a group of relatively low-cost missions to explore Earth and improve our ability to predict future changes. Earth Venture missions are selected through grant applications. Submitted by a group at Vanderbilt University, the PolSIR team will receive a grant of $37 million (£29 million) to cover operation costs, not including the cost of launch. Ralf Bennartz, chair of the department of earth and environmental science at Vanderbilt, will lead the mission along with Dong Wu of NASA's Goddard Space Flight Center in Maryland.

The mission joins NASA's many other Earth-focused missions, including the Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission, also an Earth Venture mission. At its inaugural climate change summit in December 2022, NASA highlighted several Earth science missions that will help us understand the many impacts of climate change on our planet. PolSIR is scheduled to launch in 2027, if all goes according to plan.



A This ice cloud was seen from the International Space Station in 2008

© NASA / Shutterstock

MYSTERIES OF THE UNIVERSE

WHAT CAUSED THE LARGEST COSMIC EXPLOSION EVER SEEN?

Astronomers discovered a blast ten times brighter than any recorded before

Reported by David Crookes

Imagine a cosmic explosion some 100 times the size of our Solar System and 2 trillion times brighter than the Sun. This enormous fireball blasted bright for more than a year. But astronomers only spotted it by chance. Since its discovery, researchers have been doing their utmost to work out what could have caused the flare-up, which has now been observable for more than three years. It's certainly intriguing, not to mention very rare, potentially paving the way for even more of these huge mystery explosions being discovered.

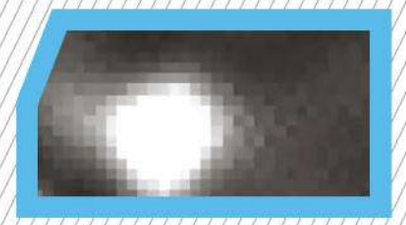
The mystery began when the Zwicky Transient Facility in California detected an explosion in 2020 during routine nightly scans of the sky. The facility was looking for anything unusual by comparing the difference between new images and a set of reference images. The blast was picked up by the Asteroid Terrestrial-impact Last Alert System (ATLAS), but escaped being noticed by humans until the following year. "At that point it was given its official name: AT 2021lwx," Dr Philip Wiseman, a research fellow at the University of Southampton, tells **All About Space**. "Once it was registered as a 'real' transient object, rather than an artefact in the images, it got picked up by algorithms that search the data for things like supernovae and tidal disruption events." Despite efforts to analyse the spectrum of the explosion's light to discover more about its chemical composition, velocity and geometry, it still took a few more months for a breakthrough.

Astronomers at the university had been working in the midst of the COVID-19 lockdowns, and there were fewer regular chats about the team's observations. While researchers sought to study AT 2021lwx because its long rise to peak brightness resembled extremely bright 'super luminous supernova', the fact the first spectrum was inconclusive meant the event was largely forgotten.

"But then, in 2022, AT 2021lwx popped up in a completely different search algorithm by a colleague who was looking for a different type of supernova – a rare calcium-rich class which tends to explode a long way away from their 'host' galaxies," Wiseman continues. "We then looked at the light curve again and thought it looked like a large supernova or a tidal disruption of a star by a black hole, but we didn't know the absolute brightness because we didn't measure

© John A. Paice

The explosion doesn't look spectacular here, as captured by a NASA space telescope, but it's the largest ever detected



AT 2021LWX BY NUMBERS

TEN
times brighter than any known supernova

THREE
times brighter than the brightest tidal disruption event

THREE
Supernova explosions last a few months. This explosion has lasted more than three years

8 BILLION
It happened 8 billion light years away

2 TRILLION
It's 2 trillion times brighter than the Sun

100
It released 100 times the total energy the Sun will in its entire lifetime

15
It brightened by a factor of 15 over four months

a distance. By looking closely at the 2021 spectrum again, we noticed some features that were consistent with a very high redshift. It placed the absolute brightness at an unprecedented level, which was when we got very excited."

Further studies of the explosion showed that it had taken place nearly 8 billion light years away, when the universe was around 6 billion years old. Its brightness was ten times that of any known supernova and three times brighter than the brightest tidal disruption event ever seen, which is where a star falls into a supermassive black hole. "The brightness of the object was easy to measure once we knew the distance," Wiseman says. "You count the amount of light in your telescope, and you know how much intensity the light loses over the distance it has travelled, so that tells you the actual brightness."

At the time, however, the team, which included astronomers from other universities, including the University of Edinburgh and Queen's University Belfast, passed the explosion off as being 'just' a quasar – a supermassive black hole steadily accreting material that stays bright for millions of years. "They can get much brighter than anything else, but are relatively common," Wiseman says. As a consequence, the team took another longer exposure to get a better spectrum, finding some lines that are also found in quasars. "We left it at that," Wiseman continues. "But then I showed that spectrum and the light curve to some quasar experts – Professor Sebastian Hönig of Southampton University being one – and he said it wasn't a quasar, it was a single explosion."

Surprised at the luminosity of the object – "Sebastian said something like, 'wow, that is incredible'," Wiseman recalls – the mystery suddenly deepened. "Quasars have a large constant flow of gas, and they only change their brightness by a factor of a few, so that means the inflow of gas only changes by a factor of a few," Wiseman explains. "To see something change by at least a factor of 100, given the limits we had on the brightness from existing images of the area, is extremely unusual." Yet if the object isn't a quasar, then what could it be? "This thing just suddenly got brighter out of absolutely nowhere," Wiseman continues. "It's very hard to explain how one minute you have nothing, then next you have incredible quantities of gas falling into a black hole. The universe tends to prefer steady changes rather than dramatic ones like this."

Intrigued, Wiseman led a more in-depth study, the findings of which were recently published in the *Monthly Notices of the Royal Astronomical Society*. They studied the object using a host of telescopes. "We took a couple of spectra with the New Technology Telescope owned by the European Southern Observatory, which allowed us to detect magnesium, carbon and a faint trace of hydrogen," Wiseman explains. "But we were in need of data at longer wavelengths, where there are strong helium lines and stronger hydrogen lines, as these are common in tidal disruption events. For that we used the Gran Telescopio Canarias, the largest single optical telescope in the world. With that, we precisely measured the velocity of hydrogen in the explosion, which showed at least two components – some fast-moving gas and some slower moving material."

The European Southern Observatory's New Technology Telescope, inaugurated in 1989, will help gather more data about AT 2021lwx

To help them measure the size and temperature of the explosion, the team also used an ultraviolet camera on the Neil Gehrels Swift Observatory's X-ray Telescope, and they were able to access archive data from the Wide-field Infrared Survey Explorer satellite. "Infrared emission comes from cooler material like dust, which typically lives further away from the black hole than the hot plasma and gas," Wiseman explains. "By measuring the delay between the optical and infrared emissions, we were able to estimate the size of the 'dusty ring', or 'torus', that often lives around a supermassive black hole."

The network of telescopes is still detecting the explosion, and work is set to continue for some years to come. New facilities such as the Vera Rubin Observatory's Legacy Survey of Space and Time could help scientists learn more about the event, and similar occurrences – in this case by monitoring the southern sky on the El Peñón peak of Cerro Pachón in northern Chile for a decade.

> "This thing suddenly got brighter out of absolutely nowhere"
> **Philip Wiseman**

© JPL/NASA

THE LIKELY CAUSE OF THE COSMIC EXPLOSION

There are several theories seeking to explain AT 2021lwx

SUPERNOVA EXPLOSION

According to the researchers, this isn't likely. "The brightness of a supernova is related to the amount of material in the star before it explodes," says Wiseman. "AT 2021lwx would have to be a star with something like 500 times the mass of the Sun that lost half of its mass in a 'wind' and then exploded into that wind, shocking it into the brightness we see. Other data, like the presence of X-rays, is also contrary to a supernova explanation."

TIDAL DISRUPTION EVENT

Again, Wiseman thinks not: "This is where a star gets too close to a black hole and is shredded. Half of the star's material forms a disc and accretes into the black hole; the other half is ejected. The brightness of a tidal disruption event is effectively governed by the size of the black hole and the size of the star. We calculated we needed a black hole at least 100 billion times the mass of the Sun, yet Sun-like stars would not be shredded by such a black hole – they'd fall straight in. You'd need a much larger star, but massive stars live fast and die young."

ACTIVE GALACTIC NUCLEUS

"AT 2021lwx could be a 'low-luminosity' active galactic nucleus – that is, a supermassive black hole that's accreting gas very gently that suddenly saw a dramatic increase in the flow rate," says Wiseman. "But we don't see any oxygen in our spectrum. Most active galactic nuclei show oxygen that's close to the supermassive black hole. The line between a low-luminosity active galactic nucleus and our final scenario is quite blurry."

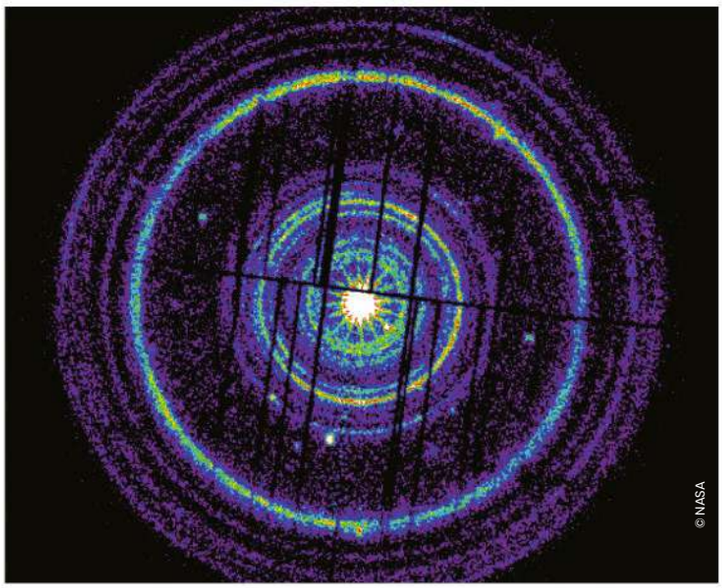
A LARGE CLOUD OF GAS

It's more plausible that a giant cloud of gas that could be many thousands of times larger than our Sun has been disrupted by a black hole. Wiseman says that the gas would be swallowed by a supermassive black hole, creating a luminous disc of accreting material. "The exact scenario will have to be modelled by theorists, and they're already working on that now," Wiseman says. Even so, it's going to be a while before we know for certain.

The team is also going to be measuring different wavelengths, including X-rays, which they say could reveal the object's surface temperature and the underlying processes that are taking place. Upgraded computational simulations will also be carried out. One thing's for sure, there's no sense that a definite answer to this particular mystery is going to be cleared up any time soon.

"We need more data at all wavelengths," Wiseman affirms. "For example, deep radio observations will help us tell whether there was a relativistic jet of plasma involved in the explosion, and constant monitoring of the light curve and spectrum will tell us how the shape, temperature, velocities and ionisation levels are changing over time. These will be crucial for more detailed models to compare against. We will also end up taking a deeper look to see if there is any associated host galaxy. Such a large supermassive black hole should have a galaxy associated with it, but in pre-explosion images we didn't detect one. We also need to take a detailed look back through the data archives and compile a complete census of similar, slightly less massive explosions and make connections and correlations."

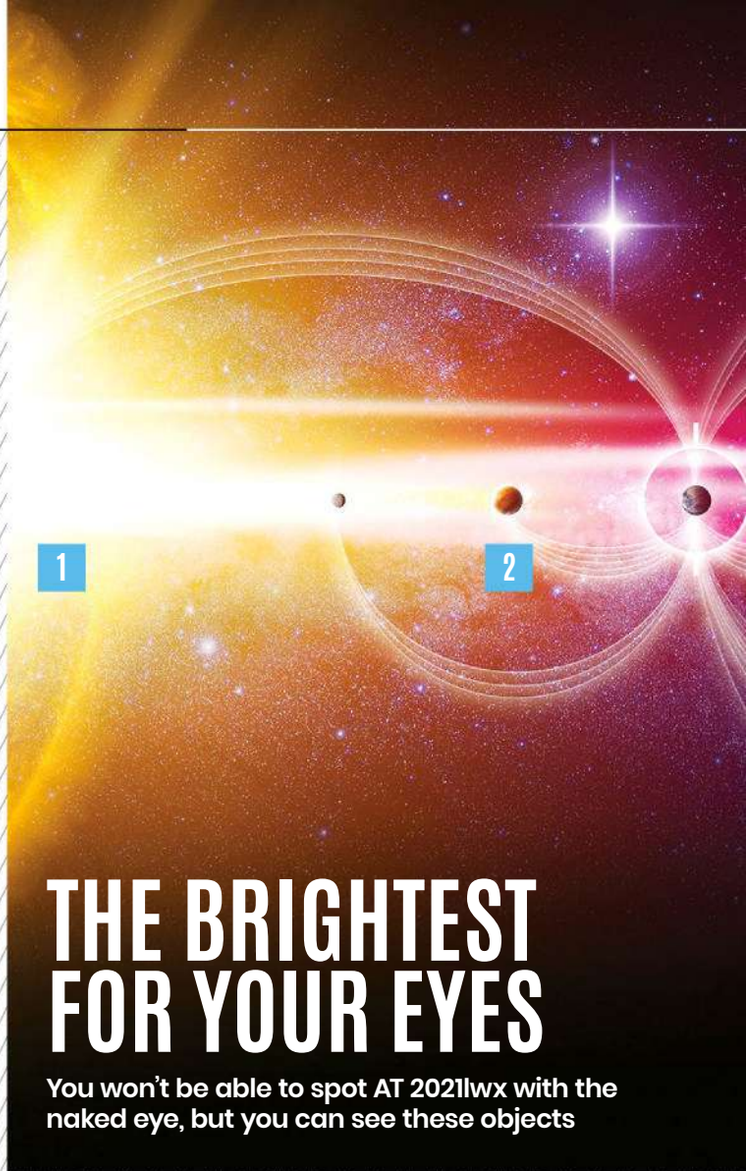
A Quasars are the brightest known objects in the universe, and researchers initially thought AT 2021lwx may have been one of them



But that's not to say that several theories haven't already been raised. "We haven't completely ruled out anything," Wiseman says, although the team thinks a supernova explosion is unlikely, and likewise a potential tidal disruption event. "The chances of a massive star randomly coming across a supermassive black hole are vanishingly small," he continues. "We also have no idea what the tidal disruption event of such a massive star would look like – the computations simply haven't been made – but the spectrum of AT 2021lwx doesn't look like most tidal disruption event spectra."

A much more likely explanation is that a giant gas cloud has been disrupted by a black hole. "It's our favourite scenario," Wiseman says. "This could potentially be part of the ring of dust and gas that surrounds many supermassive black holes, and has been knocked off orbit and ended up being disrupted. The sudden impact of all the gas falling on would create a very luminous disc of accreting material that would illuminate much of the cloud itself, which we then see as the big glowing fireball."

Intriguingly, AT 2021lwx isn't the only recent luminous discovery. In October 2022, astronomers spotted an even brighter object, GRB 221009A, which is the brightest gamma-ray burst ever detected. Discovered by the Neil Gehrels Swift Observatory and the Fermi Gamma-ray Space Telescope, the burst lasted for more than ten hours and was so bright that NASA said it effectively blinded most gamma-ray instruments in space, which meant the real intensity of the emission couldn't be recorded. But since it lasted only a fraction of the time of AT 2021lwx, it didn't release anywhere near as much

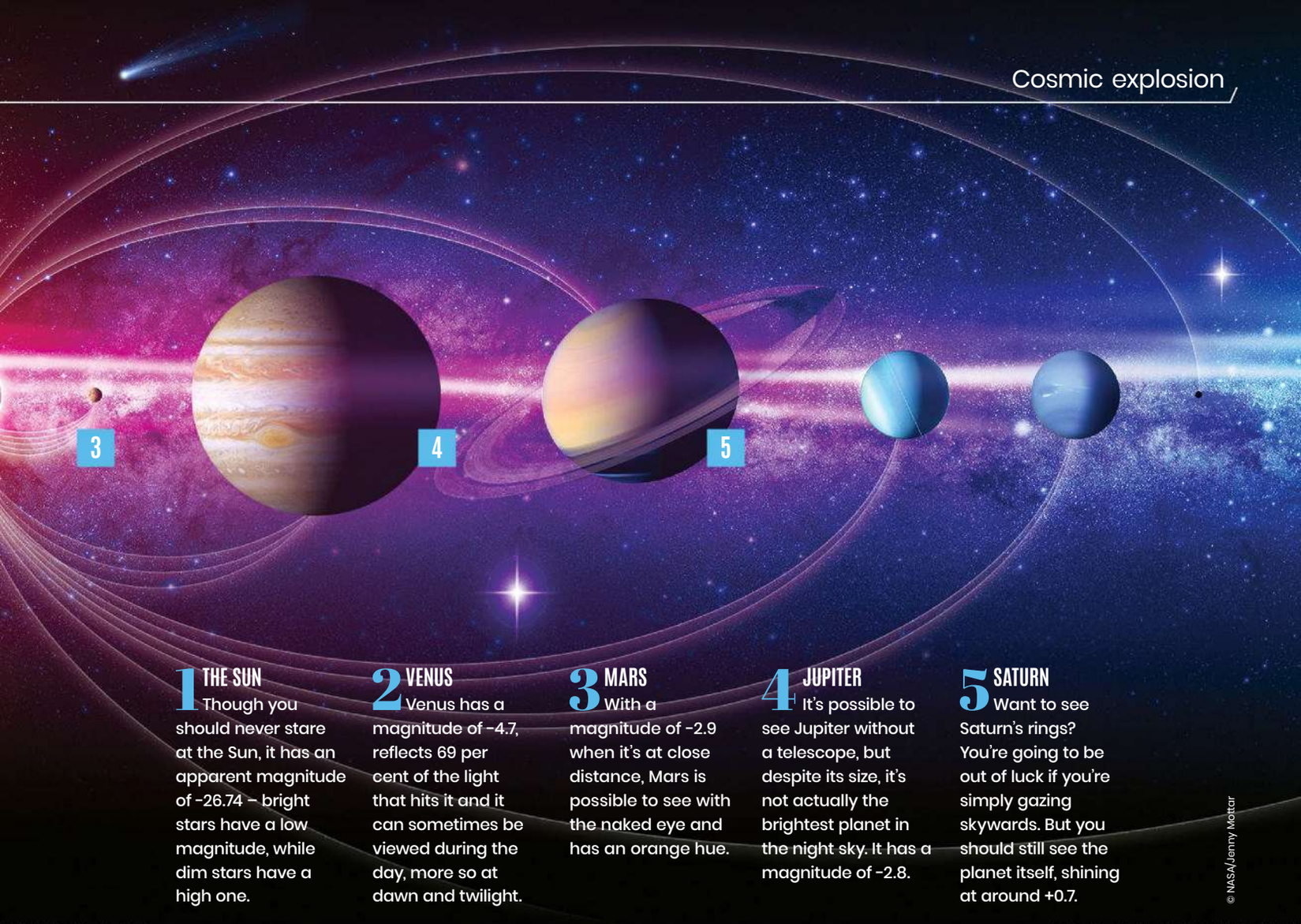


THE BRIGHTEST FOR YOUR EYES

You won't be able to spot AT 2021lwx with the naked eye, but you can see these objects

A Gamma-ray burst GRB 221009A was dubbed the brightest of all time when it was observed in October 2022

V The Zwicky Transient Facility, which first detected AT 2021lwx, is located at Palomar Observatory in San Diego County, California



1 THE SUN
Though you should never stare at the Sun, it has an apparent magnitude of -26.74 – bright stars have a low magnitude, while dim stars have a high one.

2 VENUS
Venus has a magnitude of -4.7, reflects 69 per cent of the light that hits it and it can sometimes be viewed during the day, more so at dawn and twilight.

3 MARS
With a magnitude of -2.9 when it's at close distance, Mars is possible to see with the naked eye and has an orange hue.

4 JUPITER
It's possible to see Jupiter without a telescope, but despite its size, it's not actually the brightest planet in the night sky. It has a magnitude of -2.8.

5 SATURN
Want to see Saturn's rings? You're going to be out of luck if you're simply gazing skywards. But you should still see the planet itself, shining at around +0.7.

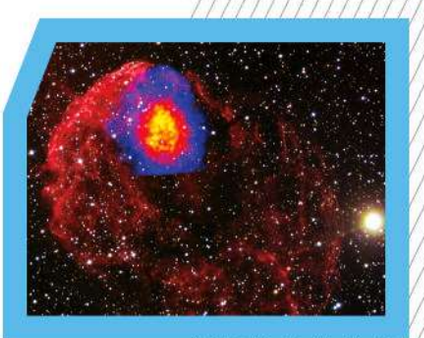
© NASA/Jenny Mottar

overall energy, so AT 2021lwx is still considered the greatest of all time.

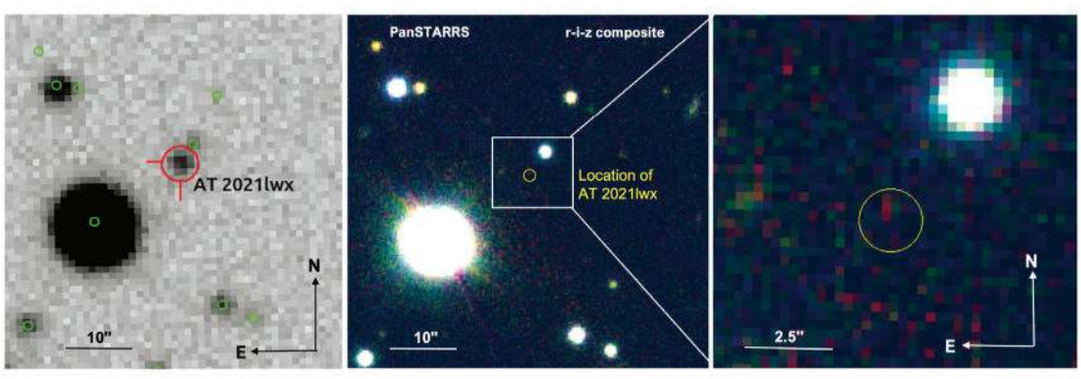
But why is it important? "The most massive and energetic processes are the ones that have the biggest impact on how structures in the universe form and evolve. There are many unanswered questions regarding the growth of supermassive black holes, the geometries and constituent parts of the inner workings of galaxies that giant explosions like this may be able to at least partially explain," Wiseman surmises.

"Also, black holes themselves are difficult to study because they don't themselves emit light. So having an apparently isolated accretion event that lasts so long and is so bright allows us to gather lots of data on how such a giant black hole affects matter and light in its vicinity. These can actually help test Einstein's theories, as well as all of the subsequent theories that built upon them."

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.



Supernovae can be as bright as an entire galaxy at their peak, but AT 2021lwx is ten times brighter than that



A Zwicky Transient Facility image of the field surrounding AT 2021lwx, obtained in 2020

© arXiv (2023). DOI:10.48550/arxiv.2302.10932

FOCUS ON

NASA'S KEPLER SPACE TELESCOPE DISCOVERED TWO MINI-NEPTUNE EXOPLANETS JUST BEFORE DYING

The spacecraft was running on fumes when it made the findings

Reported by Sharmila Kuthunur

NASA's prolific Kepler space telescope, which shut its powerful eye nearly five years ago, continued finding exoplanets even while taking its final breaths. A team of astrophysicists and citizen astronomers combing through the last chunk of data that Kepler sent home say they found two new worlds and a candidate planet closely orbiting three faint stars about 400 light years from Earth. So far these are the only exoplanets that have been discovered in the telescope's final dataset, making them the very last worlds that Kepler glimpsed just before it ran out of fuel and was shut down in late 2018.

The Kepler space telescope launched in March 2009 to stare at 150,000 selected stars in the constellation of Cygnus – a primary mission expected to last 3.5 years. The spacecraft documented dips in starlight that hinted at orbiting planets using a technique known as the 'transit method'.

Kepler's first four years in space went smoothly. But two of its four reaction wheels – devices crucial to point the observatory at its targets – failed in 2013, and it was no longer able to focus on stars precisely. A year later, scientists implemented a work-around solution that used the telescope's two good reaction wheels and its onboard thrusters to maintain a slightly unstable but workable balance.

Kepler fought on for four more years and gazed at different slices of the sky once every 80 days on a new mission known as K2, during which it discovered hundreds more exoplanets. By late August 2018, Kepler's observation power had deteriorated so much that the month-long K2 Campaign 19 – Kepler's final observation cycle – yielded only a week of high-quality data.

In that limited dataset, which included information about 33,000 additional stars, the team spotted one transit each for three exoplanets around three dim stars. Two of those planets orbit cool red dwarf stars and are what astronomers call mini-Neptunes: K2-416 b, which is 2.6 times wider than Earth and orbits its star once every 13 Earth days, and K2-417 b, which is three times wider than Earth and circles its star every 6.5 days. Both worlds are smaller than Neptune. They're enveloped by hot, tenuous atmospheres and are likely uninhabitable, researchers say. The third candidate, which circles a Sun-like star named EPIC 245978988, has not been confirmed yet.

To verify what they were seeing were really planets and not false positives because of, say, two closely orbiting stars, the team also pored over lower quality data that Kepler had collected just over a week before being decommissioned. "We tried to see what last information we could squeeze out of it," Andrew Vanderburg, a physics professor at the Massachusetts Institute of Technology's Kavli Institute for Astrophysics and Space Research, said.

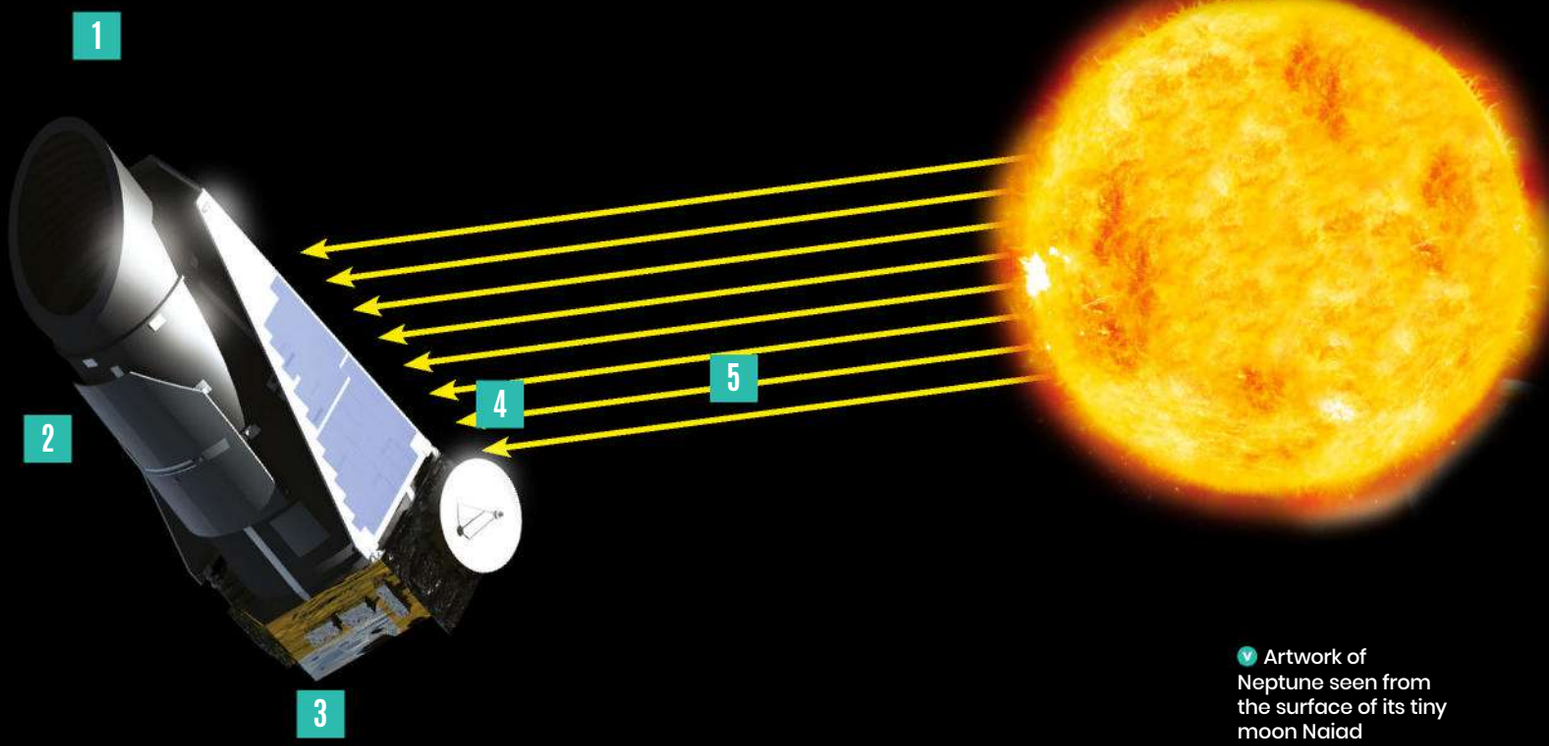
1 SUNSHADE
As its name suggests, the sunshade blocked the Sun's rays from the photometer so it could observe the universe without being obstructed.

2 PHOTOMETER
The most important instrument on Kepler was the photometer, which looked at stars to notice dips in their light as planets pass in front, known as a transit.

3 REACTION WHEELS
Only two of Kepler's four reaction wheels stayed active. These were used to point the telescope at distant stars in order to find planets.

4 SOLAR ARRAY
Kepler had to roll 90 degrees every three months to keep its solar panels pointed at the Sun and keep the telescope powered.

5 HIGH-GAIN ANTENNA
This was used to communicate with Earth, receive commands and send back data on any exoplanets Kepler found.



Artwork of Neptune seen from the surface of its tiny moon Naiad

"And we're really pushing up against the last few days – the last few minutes – of observations Kepler collected."

In those final moments, the telescope's thrusters were firing erratically, leading to sharp jumps in the collected light curves, researchers said. To validate the presence of K2-416 b and K2-417 b, the team looked for the planets' second transit around their respective stars. They found that the stars' light curves had dipped at the same depth and duration as they had during the first detected transit, confirming the candidates to be genuine exoplanets. For both transit detections, a team of citizen astronomers visually inspected the light curves of all 33,000 stars rather than relying on automated techniques commonly used in the search for exoplanets. "People doing visual surveys – looking over the data by eye – can spot novel patterns in the light curves and find single objects that are hard for automated searches to detect. And even we can't catch them all," said Tom Jacobs, a team member of the Visual Survey Group. "I have visually surveyed the complete K2 observations three times, and there are still discoveries waiting to be found."

For further confirmation, the team scoured image archives from the past 70 years to rule out the possibility of any background stars leading to false positives. They found no such possible complications for K2-416 b and K2-417 b, further confirming their planet status. But the third unconfirmed exoplanet may have a faint, red companion orbiting very close to the star that is currently difficult to resolve.

Researchers also used NASA's Transiting Exoplanet Survey Satellite (TESS), which was launched in 2018 with a similar goal as Kepler's, to validate K2-417 b's identity. TESS, which has mapped over 93 per cent of the sky so far, recently celebrated five years in space. "In many ways, Kepler passed the planet-hunting torch to TESS," Knicole Colón, a TESS project scientist at NASA's Goddard Space Flight Center in Maryland who also worked on the Kepler mission but wasn't involved in the new study, said. "Kepler's dataset continues to be a treasure trove for astronomers, and TESS helps give us new insights into its discoveries."

© NASA Getty

SPACE EXPLORATION

What causes more anxiety for an astronaut: liftoff or returning to Earth?

Liftoff. Just because it's such a physical experience. Because you're taking off, you're getting into space in eight-and-a-half minutes. There's a lot of energy being dissipated as you're being blasted off into space. The first stage is riding solid rocket motors, and they kick out 6 million pounds apiece. Combined with the engines on the Space Shuttle, that's 7.5 million pounds of thrust, and you feel every pound of that thrust in your back as you're being catapulted into space.

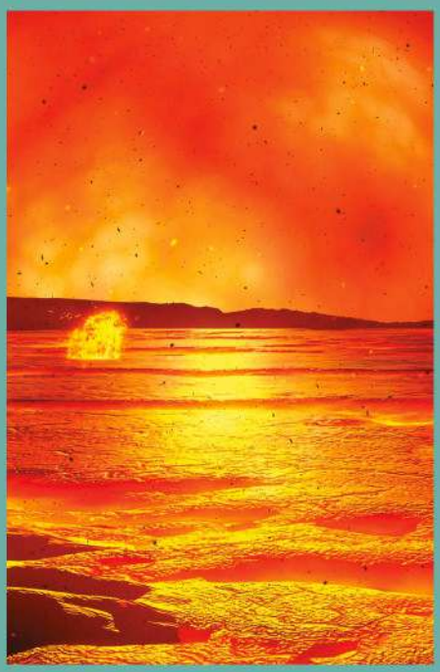
The second stage is a lot smoother because now you're only riding 1.5 million pounds, but you've been given a great push on the solid rocket motors, so it gets a lot quieter. But still, because you're above the atmosphere and heading into space at that point – because we do that around 100,000 feet (30.5 kilometres) – we begin to speed up. Now you're dealing with the physical sense of getting heavier and heavier as you're accelerating more and more, until you get to the main engine cutoff. Then at the main engine cut-off, you go from the noise, the physicality of all of that, to zero gravity within an instant and things begin to rise up around you, and you realise that you're in orbit.

Dr Bernard Harris Junior, a veteran astronaut logging over 438 hours in space in two Space Shuttle missions, STS-55 and STS-63

Leaving Earth's atmosphere means travelling at great speeds

The Sun is middle-aged

The Cassini spacecraft spent 13 years in orbit around Saturn



SOLAR SYSTEM

How far is the Sun through its life?

The Sun was formed just over 4.5 billion years ago and is about halfway through its 10-billion-year lifetime as a main-sequence star. Almost 75 per cent of the Sun's mass is comprised of hydrogen, and another 24 per cent is helium. All the other heavier elements comprise just 1.7 per cent of the Sun's mass. The Sun constantly generates energy by the nuclear fusion of hydrogen into helium at a rate of about 620 million tonnes per second. In about 5 billion years, as all the hydrogen is consumed, the Sun's outer atmosphere will expand to a red giant and likely incinerate and swallow up Earth. But life on Earth will have to find a new abode long before the red giant phase. Since the Sun is also becoming more luminous and its surface temperatures are rising, Earth's oceans will likely boil away and kill all life on Earth in a billion years or less.

Ken Kremer, a research scientist, freelance science journalist, speaker and photographer whose writings, space exploration images and Mars mosaics have been widely published in magazines, books and websites

SOLAR SYSTEM

How can the mass of Saturn's rings be measured?

During Cassini's orbits, we measured the gravity field, then we were able to calculate the mass of Saturn and, using that, the mass of its rings. When Cassini plunged into the atmosphere, we turned the high-gain antenna to Earth to send back data as we fell through the atmosphere. This happened very quickly – it was really in orbit before we got the chance to get really high-resolution pictures of the rings. Same thing for the atmosphere of the planet; we got high-resolution pictures of Saturn itself. We kept sending back data and got more and more information about the composition of the atmosphere of Saturn as we got lower and lower. We had an ion and neutral mass spectrometer sending back data.

Linda Spilker has spent over 40 years working on high-profile space missions such as Voyager and Cassini-Huygens

© Getty

SOLAR SYSTEM

What does the existence of Planet Nine tell us about the Solar System?

The Solar System has always seemed to be an oddball, and we haven't found anything quite like it. What's interesting about Planet Nine is that we always say the most common type of planet in the entire galaxy is one somewhere between the mass of Earth and the mass of Neptune, but isn't it strange that we don't have anything like that in the Solar System? Now it looks like we do.

Another thing is that most planets in the galaxy are on eccentric orbits and all of our planets are on these circular orbits. Suddenly, Planet Nine makes us look much more like the rest of the galaxy. One of the big implications for me is that by finding this very strange planet on the outer edge of our Solar System, the Solar System becomes very much more normal than it was before.

Mike Brown, professor of planetary astronomy at the California Institute of Technology. He has become well known in science for being the man who 'killed' Pluto

"Isn't it strange that we don't have anything like that in the Solar System?"

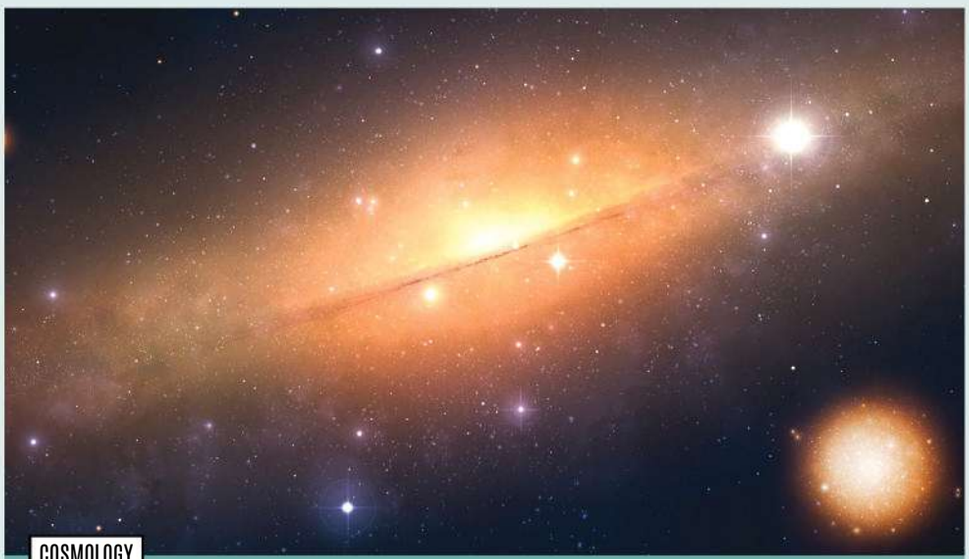
COSMOLOGY

Is there any evidence for a multiverse?

No, there's no evidence. There are strong theoretical arguments for why we might have a multiverse, but it's not clear how you would get evidence. If you have no access to it, then what does it mean for you to hypothesise the existence of something that you'll never detect? One of the things we've learned in science is that what matters are the things that you can measure, detect and interact with. If you can't interact with it, does it even make sense to talk about it? But if you're intellectually active, you will talk about it.

Neil deGrasse Tyson founded the Department of Astrophysics at the American Museum of Natural History in 1997 and is the director of the Hayden Planetarium at the Rose Center for Earth and Space in New York

- There's no current method to detect a multiverse
- Planet Nine could lie beyond Neptune's orbit
- Life might not be unique in the universe



COSMOLOGY

If the Milky Way didn't form, then would we still be here?

This depends entirely on why the Milky Way didn't form. If the Milky Way didn't form due to a lack of material, gases and dust, then no, we wouldn't be here. Generally, our understanding of galaxy formation is that it's the result of a huge cloud of material slowly being influenced by its own internal gravity. This pulls the clouds into the shapes and patterns we see. With a total absence of material, a galaxy would never form, and we would not be here either.

If the primordial Milky Way had the material but ended up forming in a different way, which resulted in a different structure, the answer is a little more complex. As the material clumps and forms stars, we expect some of those to contain planetary systems. Whether or not this results in life, such as on our planet, is still up for debate.

Sophie Allen, lead physics teacher at the National Space Academy in Leicester

© NASA / Getty

STARS

What does a star's colour tell us about it?

A star's colour can say quite a lot about the star. First of all, a star's temperature directly influences the colour of the light it emits. Cooler stars emit red light, and as the star's temperature increases it turns orange, yellow, then to white and finally blue. The colour can also give us an insight to a star's age. Blue stars are hotter and are therefore burning their fuel reserves faster. Blue stars found on the main sequence are typically young stars. As stars get older and they run out of hydrogen, they start to cool. As this happens, they tend to shift towards the redder end of the spectrum. However, we can't infer that all red stars are old. Some of them may have been cool from the start.

Josh Barker, education and outreach officer at Space Park Leicester

WHAT'S IN THE SKY?

What to look out for during this observing period

In this issue...

80 What's in the sky? The nights are still bright, but they're a little longer each day that passes

82 Planetarium Where you can find the planets this month and the phases of the Moon

84 Month's planets Uranus is a naked-eye target for skywatchers under favourable conditions

86 Moon tour Take an imaginary trip to the site of the first lunar base

87 Naked eye and binocular targets Distant galaxies and fascinating stars can be seen late on summer nights

88 Deep sky challenge The summer skies are stuffed full of amazing objects for your telescope if you're prepared to stay up late

90 The Northern Hemisphere The central part of our home galaxy is teeming with star clusters to enjoy

92 Review We put the Pococo Galaxy projector to the test

96 In the shops Our pick of the best gifts and accessories for astronomy and space fans

20 JULY
Conjunction between the Moon and Venus in Leo

21 JULY
The Moon and Mars make a close approach, within 2°57' of each other in Leo

22 JULY
Pluto reaches opposition, glowing at magnitude +14.9 in Capricornus

28 JULY
The Moon will pass in front of the star Delta Scorpii, creating a lunar occultation

29 JULY
The Piscis Austrinid meteor shower reaches its peak

30 JULY
The Southern Delta Aquariid meteor shower reaches its peak

3 AUGUST
The Moon and Saturn make a close approach, within 2°15' of each other in Aquarius

9 AUGUST
Mercury will reach half phase, also known as dichotomy

9 AUGUST
The Moon and the Pleiades (Messier 45) pass within 1°20' of each other in Taurus

9 AUGUST
Mercury is at its greatest elongation east in the evening sky at +0.3

"Asteroid 10 Hygiea reaches opposition, glowing at magnitude +9.7 in Aquarius"

10 AUGUST
Asteroid 10 Hygiea reaches opposition, glowing at magnitude +9.7 in Aquarius

Naked eye | Naked eye warning (TAKE CARE!) | Binoculars | Small telescope | Medium telescope | Large telescope | Solar eclipse | Solstice

25 JULY

Mercury is at its highest altitude in the evening sky, dazzling at magnitude +0.3

31 JULY

The Alpha Capricornid meteor shower reaches its peak

8 AUGUST

The Moon and Jupiter make a close approach, within 2°39' of each other in Aries

Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light

Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis we see different parts of the sky throughout the night.

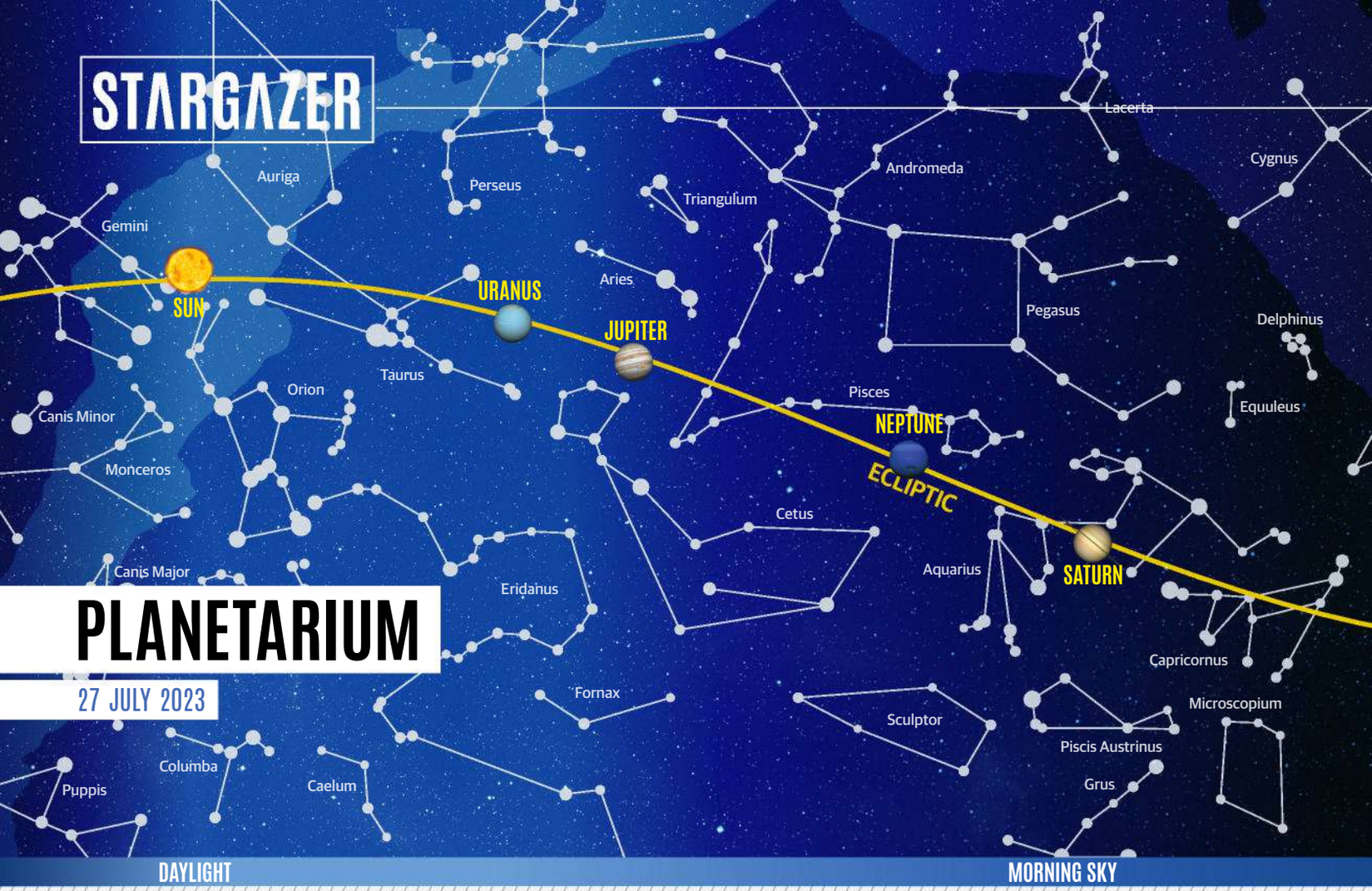
Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of –1.0 is brighter than +2.0.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

© NASA; ESA; ESO; Getty



PLANETARIUM

27 JULY 2023

MOON CALENDAR

* The Moon does not pass the meridian on 31 July

13 JUL	14 JUL	15 JUL	16 JUL
18.1%	10.8%	5.3%	1.8%
01:14 / 18:00	01:39 / 19:13	02:13 / 20:16	03:00 / 21:07

17 JUL	18 JUL	19 JUL	20 JUL	21 JUL	22 JUL	23 JUL
NM						
0.3%	0.7%	3.1%	7.3%	13.1%	20.3%	28.7%
03:58 / 21:44	05:06 / 22:11	06:18 / 22:30	07:30 / 22:45	08:42 / 22:58	09:52 / 23:08	11:02 / 23:19

24 JUL	25 JUL	26 JUL	27 JUL	28 JUL	29 JUL	30 JUL
	FQ					
38.1%	48.3%	58.8%	69.3%	79.3%	88.0%	94.8%
12:13 / 23:29	13:26 / 23:42	14:43 / 23:57	16:04 / --:--	00:18 / 17:28	00:49 / 18:49	01:35 / 19:57

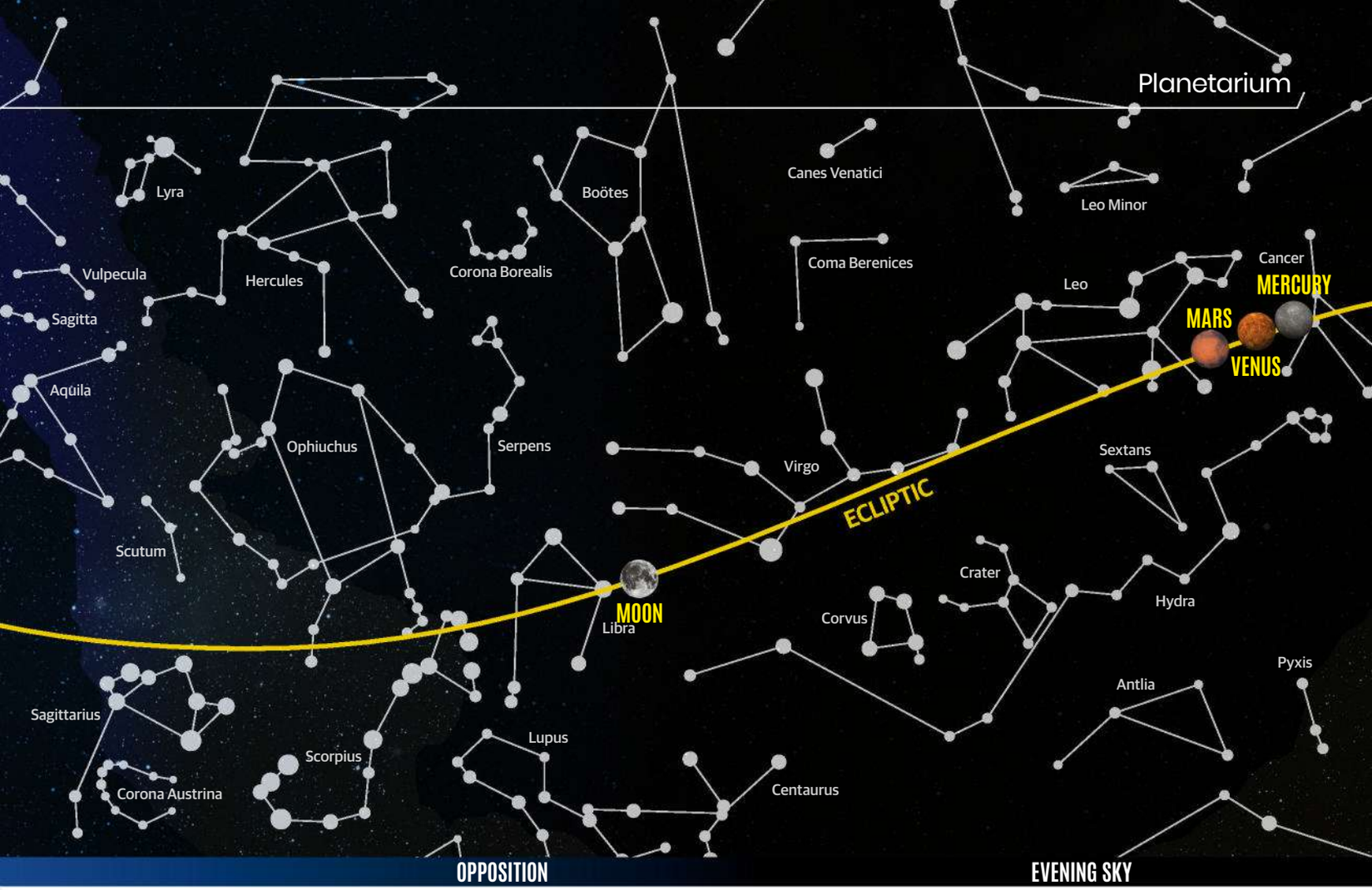
31 JUL	1 AUG	2 AUG	3 AUG	4 AUG	5 AUG	6 AUG
	FM					
---%*	98.8%	99.7%	97.3%	91.8%	83.9%	74.1%
02:41 / 20:48	04:07 / 21:22	05.42 / 21:46	07:18 / 22:04	08:50 / 22:19	10:19 / 22:32	11:44 / 22:45

7 AUG	8 AUG	9 AUG	10 AUG
	TQ		
63.4%	52.3%	41.5%	31.3%
13:07 / 23:00	14:29 / 23:18	15:50 / 23:41	17:05 / --:--

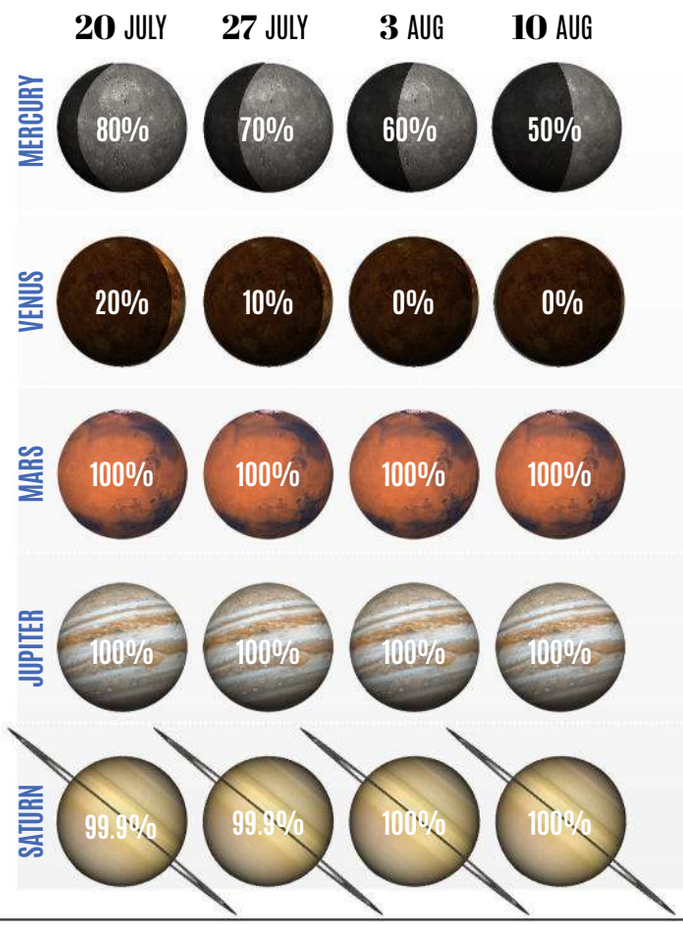
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE



PLANET POSITIONS

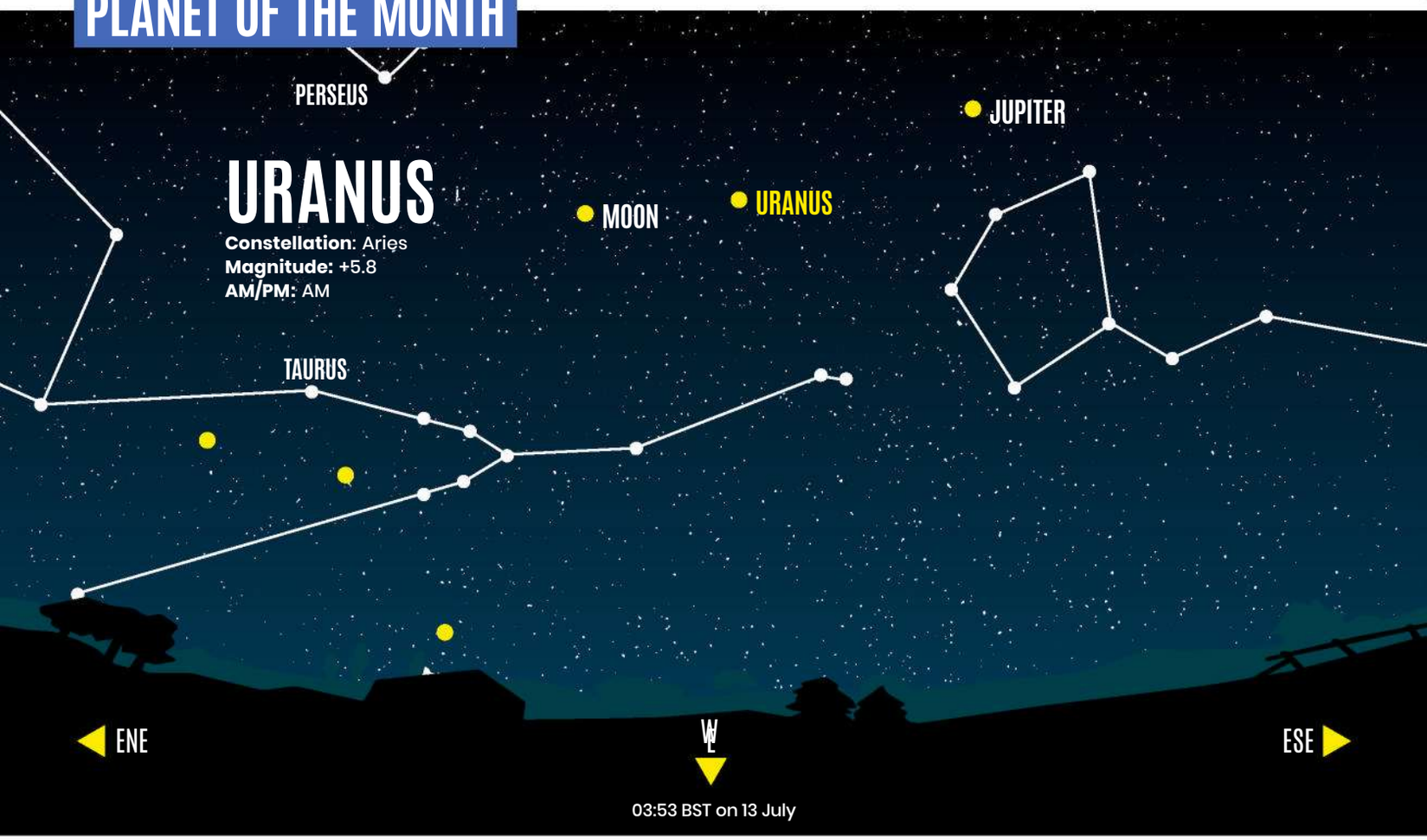
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
13 JUL	08h 23m 51s	+21° 12' 46"	Cancer	-0.9	05:57	22:03
20 JUL	09h 14m 58s	+17° 27' 16"	Cancer	-0.4	06:45	22:02
27 JUL	09h 57m 29s	+13° 08' 22"	Leo	-0.1	07:26	21:52
3 AUG	10h 32m 11s	+08° 45' 04"	Leo	-0.1	07:57	21:35
10 AUG	10h 59m 05s	+04° 41' 41"	Leo	-0.3	08:17	21:13
13 JUL	09h 52m 46s	+11° 21' 06"	Leo	-4.5	08:26	22:32
20 JUL	09h 57m 07s	+09° 29' 05"	Leo	-4.4	08:13	21:59
27 JUL	09h 54m 29s	+08° 03' 59"	Leo	-4.3	07:51	21:21
3 AUG	09h 44m 36s	+07° 16' 49"	Leo	-4.2	07:17	20:40
10 AUG	09h 29m 04s	+07° 13' 47"	Leo	-4.0	06:35	19:56
13 JUL	10h 14m 32s	+12° 03' 59"	Leo	+1.7	08:44	22:58
20 JUL	10h 30m 43s	+10° 27' 21"	Leo	+1.8	08:41	22:38
27 JUL	10h 46m 52s	+08° 47' 14"	Leo	+1.8	08:39	22:17
3 AUG	11h 03m 00s	+07° 04' 09"	Leo	+1.8	08:37	21:57
10 AUG	11h 19m 08s	+05° 18' 31"	Leo	+1.8	08:34	21:36
13 JUL	02h 35m 25s	+13° 59' 18"	Aries	-2.3	00:55	15:31
20 JUL	02h 39m 22s	+14° 16' 44"	Aries	-2.3	00:30	15:09
27 JUL	02h 42m 53s	+14° 31' 46"	Aries	-2.4	00:05	14:46
3 AUG	02h 46m 43s	+14° 47' 30"	Aries	-2.4	23:32	14:16
10 AUG	02h 48m 28s	+14° 54' 25"	Aries	-2.5	23:13	13:59
13 JUL	22h 35m 01s	-10° 43' 38"	Aquarius	+0.7	23:05	09:22
20 JUL	22h 33m 53s	-10° 51' 49"	Aquarius	+0.7	22:37	08:52
27 JUL	22h 32m 30s	11° 01' 17"	Aquarius	+0.6	22:09	08:22
3 AUG	22h 30m 54s	-11° 11' 47"	Aquarius	+0.6	21:41	07:52
10 AUG	22h 29m 09s	-11° 23' 05"	Aquarius	+0.5	21:13	07:22

THIS MONTH'S PLANETS

Uranus is a naked-eye target for skywatchers under favourable conditions

PLANET OF THE MONTH



It's really surprising how few amateur astronomers and skywatchers – even the more experienced ones – have never seen Uranus. It's because of its reputation for being 'difficult'. Many people don't even bother to look for this enigmatic ice giant planet, believing it's very hard to see, but in fact it isn't. Even a very modest pair of binoculars will allow you to track it down and see it as a green-hued star. The trick is knowing where and when to look for it. Fortunately, at the start of this month Uranus will be very well placed for those wanting to see it - close to strikingly bright Jupiter in the sky, around 11 degrees to its east. Unlike most of the worlds on view this month, Uranus will also be visible in a dark sky, which will make it easier to see, too.

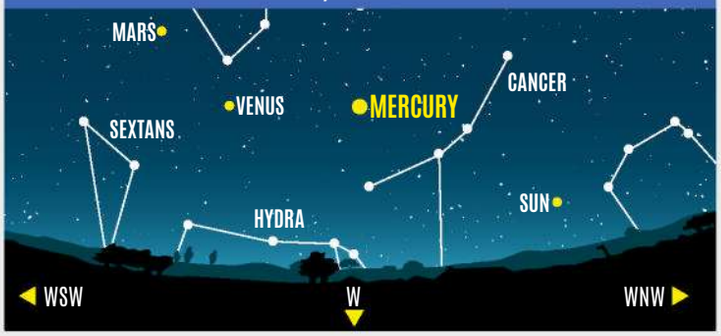
Early on the morning of 13 July there will be a great opportunity for first timers to see Uranus. On that morning Uranus will be found halfway between a lovely waning crescent Moon to its left, and vividly bright Jupiter to its right. If you scan the sky halfway between those two bodies with your binoculars, you'll see a star with a very definite green tinge – that will be Uranus.

Although Hubble and the James Webb Space Telescope now regularly take spectacular images of Uranus, showing us details in its atmosphere and its rings, it's been many years since we had a really close-up view of it. No space probes have flown past Uranus since NASA's Voyager 2 probe flew past it in January 1986, just four days before the Space Shuttle Challenger was lost in the tragic accident that killed all seven of its crew. Voyager 2 sent back the first high-quality images of the planet's creamy, turquoise-hued atmosphere and scudding blue-white clouds.

Many planetary scientists and astronomers are hoping NASA or another space agency sends a probe to Uranus soon, eager to see what fascinating sights could be seen using today's modern cameras and imaging equipment. There are no firm plans for such a mission yet, but with so many rovers and landers going to Mars year after year, many scientists believe Uranus deserves a dedicated mission too.

In the meantime, try to find Uranus for yourself during the month ahead. It's not a spectacular sight by any means, but when you see it and think just how far away it is, it certainly is a special one.

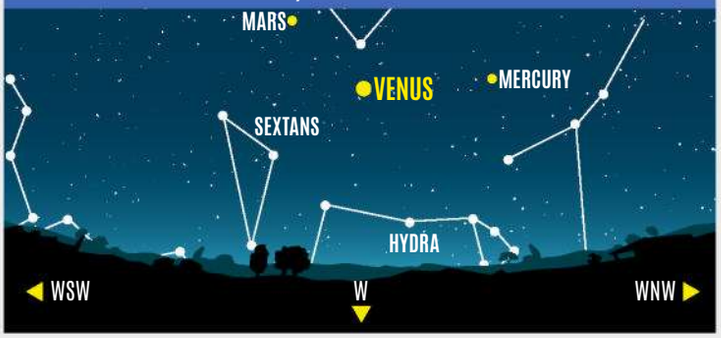
MERCURY 20:00 BST on 20 July



Constellation: Cancer **Magnitude:** -0.2 **AM/PM:** PM

In mid-July Mercury will be shining low in the northwest after sunset, close to the much-loved star cluster Messier 44, the Beehive Cluster. Higher in a dark sky, Mercury's magnitude of -0.2 would make it an easy naked-eye object, but seeing it in the month ahead will be quite a challenge as it will always be low in a bright twilight sky.

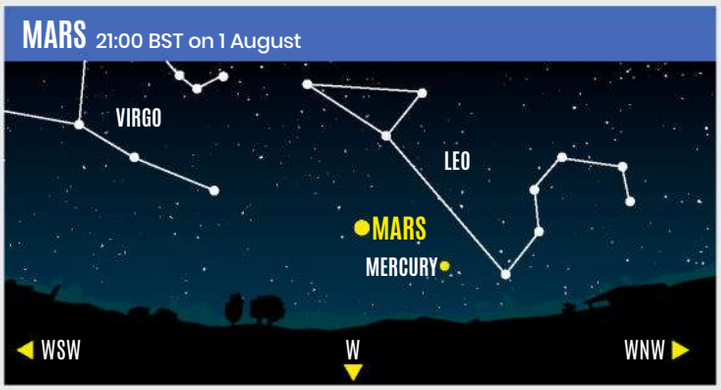
VENUS 20:00 BST on 20 July



Constellation: Leo **Magnitude:** -4.5 **AM/PM:** PM

At the start of our observing period Venus is still a bright 'evening star', shining low in the west after sunset and clearly visible to the naked eye, close to the star Regulus, but will set only an hour after the Sun. As August approaches Venus will set a little sooner each evening, heading towards the Sun.

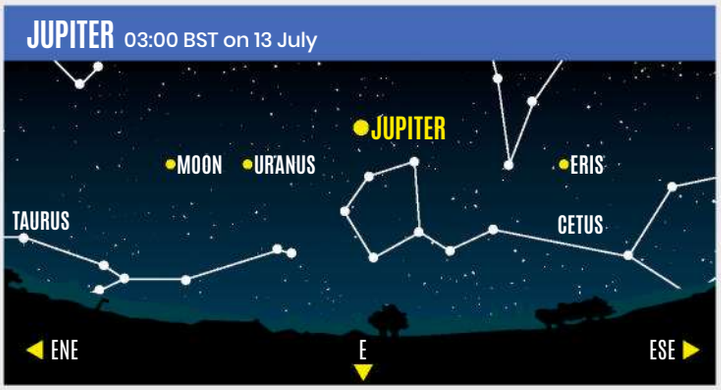
MARS 21:00 BST on 1 August



Constellation: Leo **Magnitude:** +1.7 **AM/PM:** PM

Hanging low in the west with a magnitude of only +1.7, you'll probably need a pair of binoculars to pick Mars out clearly from the bright evening sky before it sets. At the start of our observing window Mars will be very close to Regulus, the brightest star in Leo, but as July drifts into August it will pull away from the star.

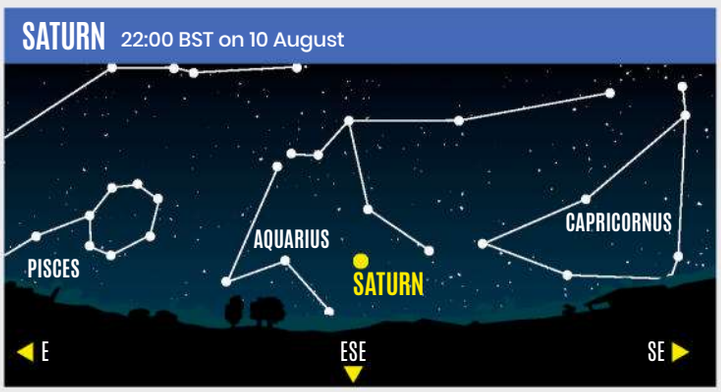
JUPITER 03:00 BST on 13 July



Constellation: Aries **Magnitude:** -2.3 **AM/PM:** AM

Jupiter will be a bright 'morning star' all through the month ahead, easily visible to the naked eye as a strikingly bright blue-white 'star' shining in the southeast long before sunrise. Before sunrise on 13 July a beautiful waning crescent Moon will be shining to the lower left of Jupiter, making a lovely sight.

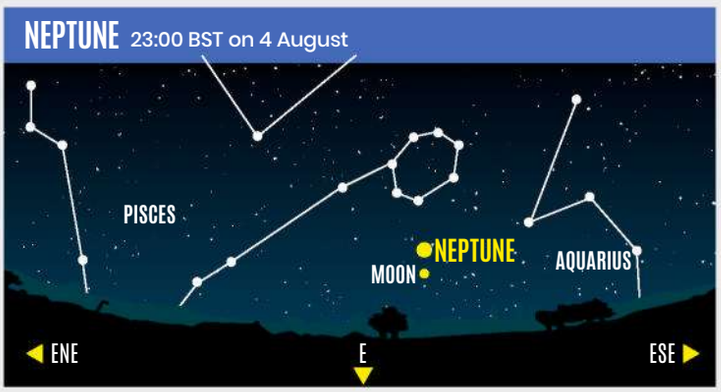
SATURN 22:00 BST on 10 August



Constellation: Aquarius **Magnitude:** +0.7 **AM/PM:** PM

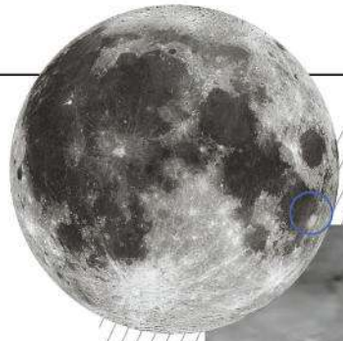
Saturn will be an evening object during the month ahead, visible all through the night. In mid-July it will rise in the east at around 23.20, clearly visible as a yellow-white star to the naked eye and leading the way for much brighter Jupiter, which will rise roughly an hour and a half later.

NEPTUNE 23:00 BST on 4 August



Constellation: Pisces **Magnitude:** +7.9 **AM/PM:** PM

This remote ice giant world will rise in the east at around 23.45, not long after Saturn has cleared the horizon, but by the end of our observing period Neptune will be rising at 22:00. On the evening of 4 August, a waning gibbous Moon will be shining just under three degrees below Neptune, which will help greatly if you want to find it.



MOON TOUR

SHACKLETON CRATER

Take an imaginary trip to the site of the first lunar base – in both fact and fiction

One popular science-fiction TV series is *For All Mankind*, which chronicles a fascinating and thrilling alternative history of the US space program. In the alternate history, the Soviets beat the US to the Moon – Alexei Leonov takes that first small step instead of Neil Armstrong, quickly followed by a female cosmonaut, and it all follows on from there. By the mid-1970s there have been 25 Apollo missions, carrying both male and female crews, and both superpowers have small military outposts on the Moon, built on the rim of a crater down at the Moon's south pole, Shackleton. Why there? Its shadowy depths, never illuminated by the Sun, contain priceless deposits of ice that can be processed to make fuel and water, allowing lunar settlers to 'live off the land' instead of lugging those resources from Earth.

Shackleton is shown so realistically in the series that many fans of the show have been asking astronomers if they could show them 'the crater from the TV series' with their telescopes. Unfortunately, that's not possible. Being at the lunar south pole, Shackleton is only ever seen edge-on from Earth and is never illuminated by the Sun, which is exactly why it was chosen as the site of the superpowers' bases in the series, and also why NASA is planning to establish a real permanent base there after the crewed Artemis missions have surveyed the area.

Real life will mirror fiction in this way – just like in the TV series, orbital surveys of Shackleton have detected traces of water within the crater, perhaps ice deposited there by comets. But unlike the glittering veins and chunks of pure ice shown being hacked out of the crater walls by *For All Mankind*'s axe-wielding astronauts, in real life the water found in the crater is all mixed in with the rocks and dust, so it will require a lot of processing to access. That's just chemistry and engineering, though, two things NASA is great at.

TOP TIP!

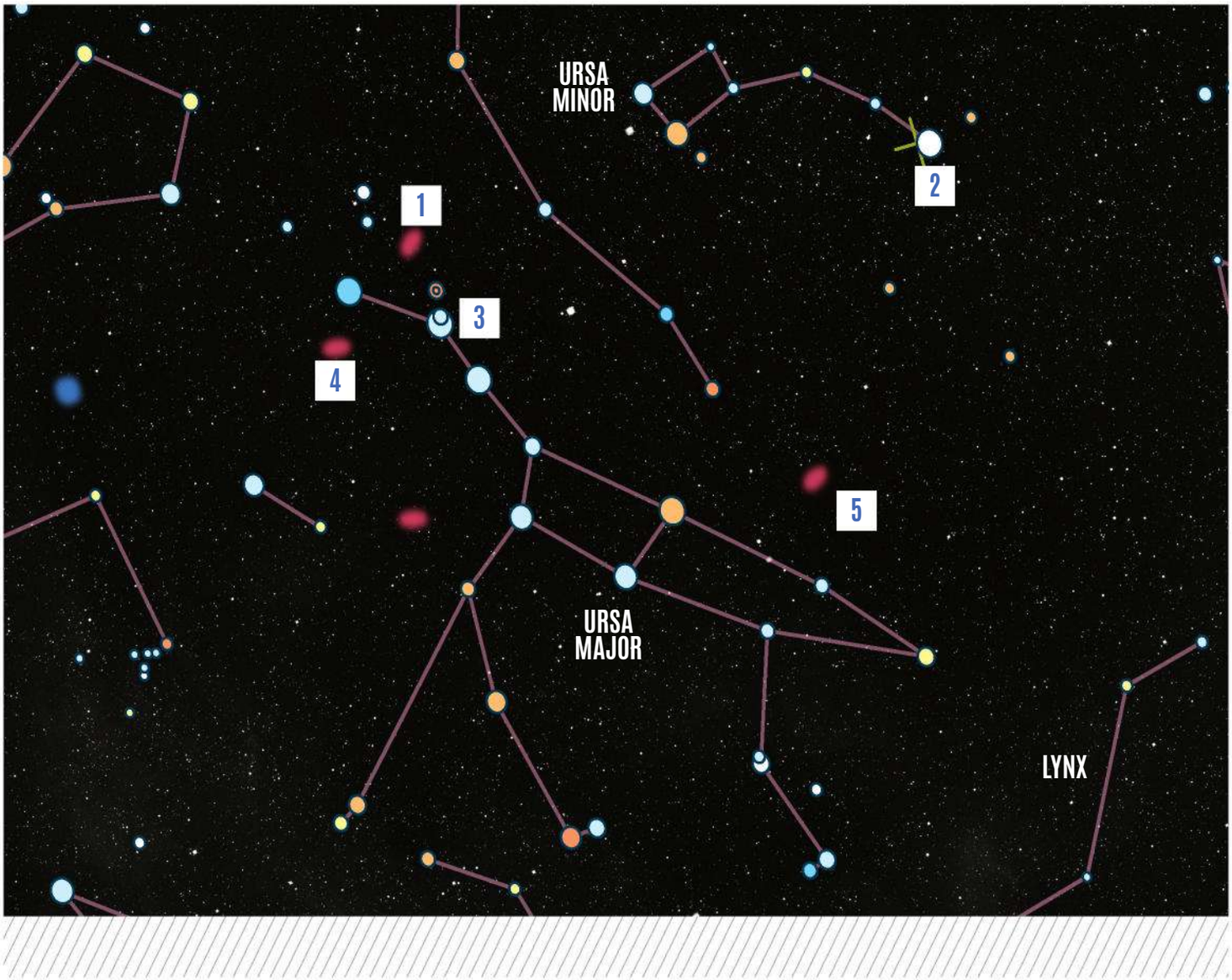
Look on NASA websites for images of Shackleton crater taken from orbit.

Appropriately named after the famous south polar explorer Ernest Shackleton, the crater itself is quite small. In fact, if it were anywhere else on the Moon it would be quite unremarkable. Only 12 kilometres (7.4 miles) across and just over four kilometres (2.4 miles) deep, it's only interesting because of a useful combination of the water deposits detected within it and the height of several of the tallest peaks along its rim. These lofty summits are bathed in almost permanent sunlight, which means a base built on Shackleton's rim could be powered by solar panels on the peaks, with its explorers and scientists sustained by water mined from within the crater.

It's a little unfortunate that we can't see Shackleton properly from Earth, because in the years to come it's going to become a very important and busy place, a lunar beachhead in the human exploration of the Solar System from where we will strike out to asteroids and Mars. As NASA gears up towards its return to the Moon, Shackleton will become the target for many robotic missions, perhaps including rovers, so even though you won't be able to see it directly through your binoculars or telescope, it's good to know where Shackleton is. On a clear night when the Moon is high and bright in the sky, you should cast your eyes down towards the south pole of the Moon and imagine what future astronauts will see and do there, more than half a century after their fictional counterparts explored it on TV.

If you're one of our many younger readers you might bounce around the rim of Shackleton crater yourself one day, or gaze down into its depths from one of its peaks of eternal light, looking down to where your colleagues are mining water – not just for you, but for all humankind.

© ESA



NAKED EYE AND BINOCULAR TARGETS

Distant galaxies and fascinating stars can be seen late on summer nights

1 Pinwheel Galaxy (Messier 101)

Close to the end of the Big Dipper's handle, the magnitude +7.9 spiral galaxy Messier 101 can be seen through binoculars as a small round smudge. Some 27 million light years away, this galaxy is over 170,000 light years across, making it twice the Milky Way's size.

2 Polaris (Alpha Ursae Minoris)

The famous Polaris, the Pole Star, isn't as bright as many have been led to believe. Far from being the brightest star in the sky, as new stargazers expect, at magnitude +2.0 it's only the 48th-brightest star in the night sky. It's approximately 430 light years from Earth.

3 Mizar and Alcor

In the centre of the Big Dipper's handle, Mizar and Alcor form one of the most famous double stars in the sky. It even used to be used as a test of eyesight, because people with good vision can see both stars without any optical assistance. The pair is roughly 85 light years away.

4 Whirlpool Galaxy (Messier 51)

A magnitude +8.0 spiral galaxy, Messier 51 is 23 million light years away. Nicknamed the Whirlpool Galaxy, it can be found just off the end of the Big Dipper's curved handle. Binoculars show it as a small out-of-focus star. Up close, it's roughly the same size as our own galaxy, the Milky Way.

5 Bode's Galaxy and the Cigar Galaxy

This famous pair of galaxies fit in the same binocular field of view. Both are huge spirals, but being so far away they appear very small in the sky, like a pair of tiny smudges. Round Messier 81 is the brighter of the two, while Messier 82 appears elongated, much like a cigar.

4 Lagoon Nebula (Messier 8)

DEEP SKY CHALLENGE

STELLAR TREASURES OF THE ARCHER AND SCORPION

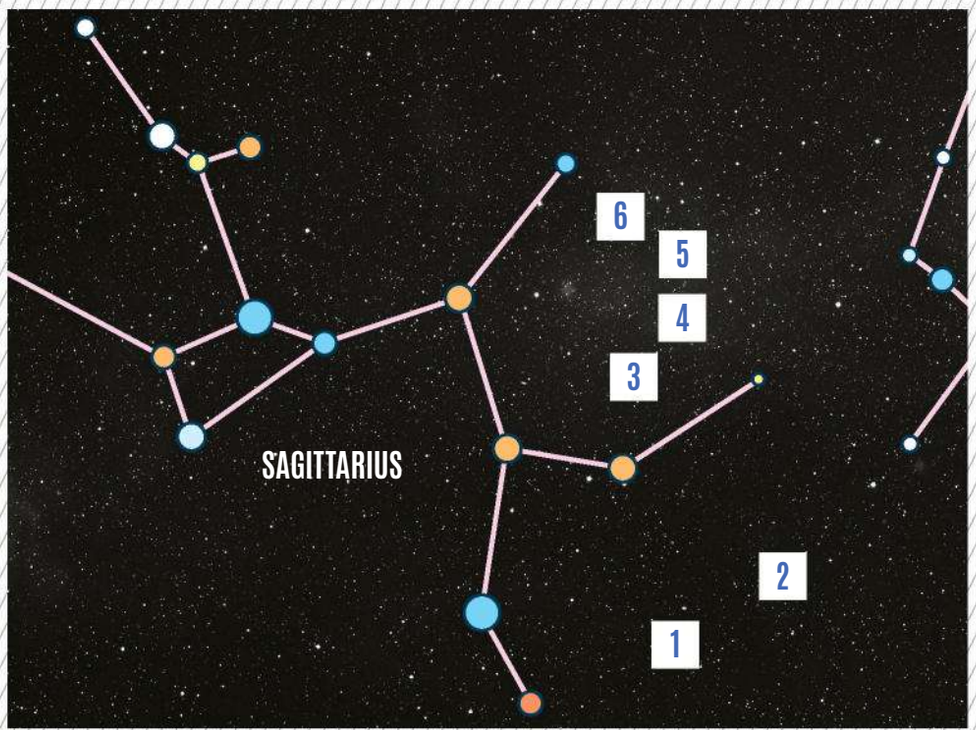
The summer skies are stuffed full of amazing objects for your telescope if you're prepared to stay up late

Summer in mid-northern latitudes gives us short nights which are never truly dark, which can wreak havoc on your viewing plans. However, they're dark enough to see some real celestial wonders. The Milky Way arcs almost north to south at this time of year and brings with it all kinds of deep-sky gems, including open star clusters, globular star clusters and nebulae on which to feast your eyes.

Down near the southern horizon you'll find the constellations of Scorpius and Sagittarius, which are packed with many such objects. For example, there's open star cluster Messier 7 – this object can be challenging for Northern Hemisphere observers as it's so close to the horizon during this time of year. On the other hand, the exquisite Eagle Nebula, also known as Messier 16, is much more straightforward to spot. Take a tour of just a few of the glorious objects within the borders of the Archer and the Scorpion for almost any size of telescope – they'll be worth staying up for!

3 NGC 6553

"At around 100 million years old, the majority of the stars within this open cluster are hot, young, blue stars"



1 PTOLEMY'S CLUSTER (MESSIER 7)

A treat through a telescope. Sitting close to the 'stinger' of Scorpius, it's a challenging object for observers in northern latitudes.

2 BUTTERFLY CLUSTER (MESSIER 6)

This is another great cluster for a small telescope. At around 100 million years old, the majority of the stars within this open cluster are hot, young, blue stars.

3 NGC 6553

This is a very loose globular star cluster. Packed with stars of magnitude +20.0 or dimmer, you'll require a telescope with a large aperture to observe it effectively.

4 LAGOON NEBULA (MESSIER 8)

A small telescope at low power will see a faint oval patch of light with a definite core. The nebula is currently undergoing a period of active star formation. The group covers roughly 14 arcminutes of sky.

5 TRIFID NEBULA (MESSIER 20)

Messier 20 consists of an emission nebula, a dark nebula and a reflection and open cluster. The nebula is quite bright, with a magnitude of +9.0, making it a good target for small telescopes.

6 MESSIER 21

Tightly packed, this open cluster is best seen at medium power through a larger aperture telescope. Messier 21 consists mainly of small, faint stars, but it's also home to a few blue giants.

1 Ptolemy's Cluster (Messier 7)

© NASA, Wiki / PD

NORTHERN HEMISPHERE

The central part of our galaxy is teeming with star clusters to enjoy

Fully in the midst of summer, the short warmer nights offer a splendid selection of nebulae, star clusters and bright stars to observe. Red supergiant Arcturus proudly makes its appearance known in the constellation of Boötes. The unmistakable Summer Triangle is easily observed this month, with the stars Altair, Deneb and Vega in the constellations of Aquila, Cygnus and Lyra respectively marking each of its corners. Summer is an ideal time to see the Milky Way, with Sagittarius and Scorpius marking its centre – here you'll be able to see a selection of clusters, including the Ptolemy Cluster, also known as Messier 7.

Ptolemy's Cluster (Messier 7)

North America Nebula, Pelican Nebula, the Sadyr Region, Crescent Nebula and Tulip Nebula in Cygnus

Summer Milky Way

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

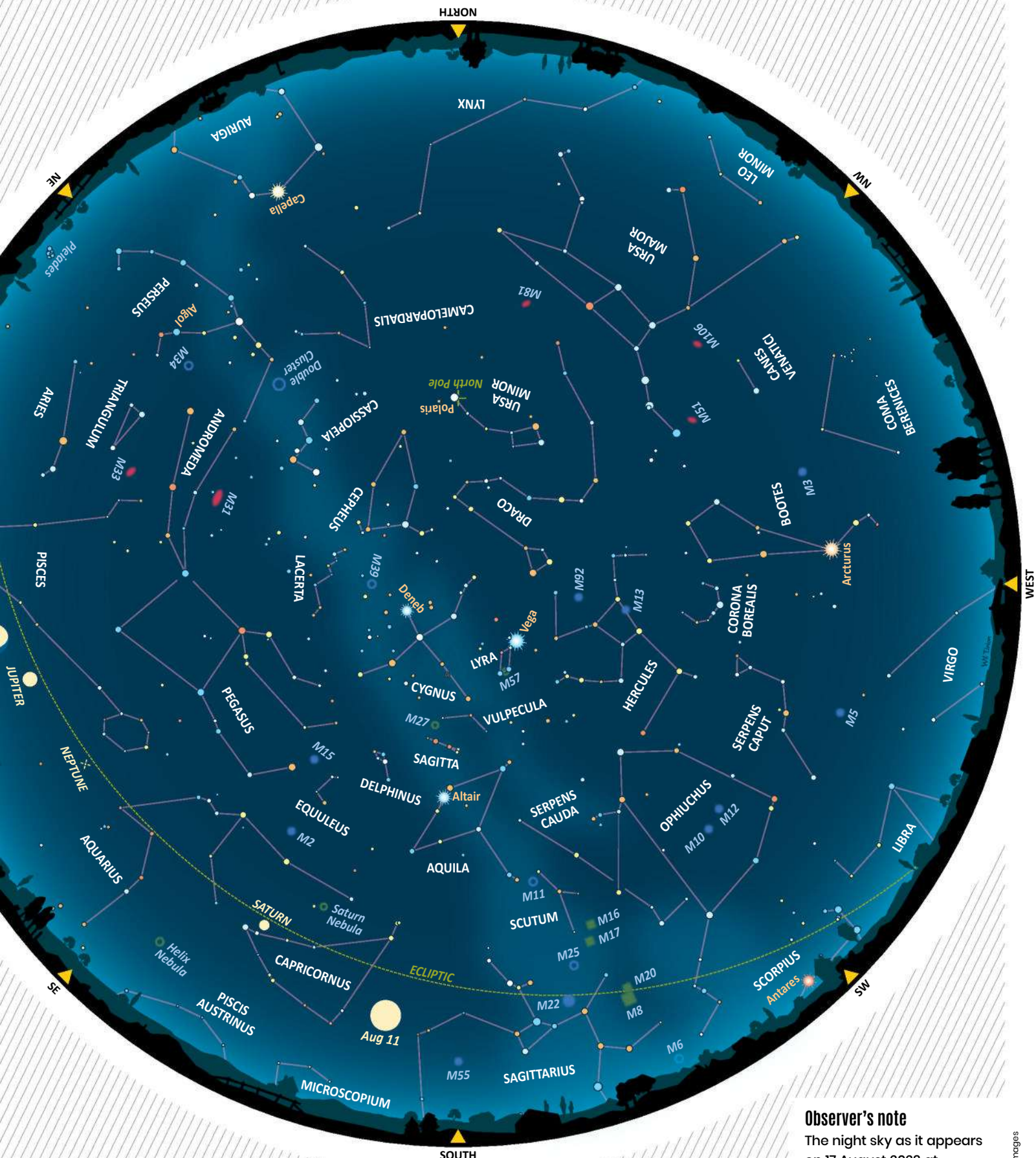
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O–B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note

The night sky as it appears on 17 August 2023 at approximately 22:00 (BST)

© Getty images

REVIEW

POCOCO GALAXY PROJECTOR

This rechargeable star projector emits bright, colourful and sharp imagery that gives the best star projectors we've tested a run for their money

Reviewed by Tantse Walter

DETAILS

Cost: £113.66 / $109.99

Size: 157 by 120 by 120 millimetres

Bulb type: LED

Rotation: Yes

Sleep timer: Yes

Speaker: No

Projection surface: 12 square metres

The Pococo Galaxy star projector aims to compete with the best of them. While researching the vast star projector market, we could see that the Pococo Galaxy home planetarium has an extensive expandable image disc collection, uses LED projection and a focus ring, doesn't have laser 'stars', has a small spherical form factor and the image quality looked sharp and vivid. This all sounded very similar to the Sega Homestar Flux that we reviewed previously. The most significant notable difference, however, is the huge price disparity. We felt we needed to put it through its paces to see whether it competes with the more widely known, more expensive home planetarium star projectors, given that it seems to have very similar functionality. Pococo claims this is an eco-friendly addition to the star projector collection, so we wanted to examine this more closely as well.

The Pococo Galaxy star projector is a simple and stylish model with lots of potential. Interchangeable discs of vivid images on a slow rotation immerse the user in a dreamy space-like ambiance. The Pococo Galaxy projector is a globe-shaped home planetarium on a fixed stand that can pivot forwards and backward 60 degrees.

The projector itself is sleek and colourful, making it a nice addition to a room even when not in use

BEST FOR...

- FAMILIES
- CHILDREN
- WELLNESS
- THE HOME

The Pococo Galaxy Projector offers excellent image quality

A white version is available if you like a more simple look

While this doesn't sound as flexible as some other projectors we've reviewed, remember that you can physically turn the whole device around 360 degrees too. The 60 degrees of flexibility in the stand means it's meant to be pointed at the ceiling or high up at the wall, where most people would want it anyway.

Even the projector's box is eye-catching. It's nicely designed and would be great to receive as a gift. The pink-and-blue-shaded box has 'shelf appeal' and would appeal to children as a night light as well as a young teenage audience. Pococo even includes a little postcard to use as a gift card, which we think is a nice touch.

Everything arrives wrapped in a non-recyclable plastic film and each individual disc is stored in an individual plastic case. In the future, we'd like to see Pococo use an alternative for these cases, like cardboard sleeves. The device should also use recycled materials and the packaging should be truly biodegradable. So while the sentiment is there, which is a good thing, Pococo needs to work on actually increasing its green credentials its going to use 'eco-friendly design' as a selling point.

"The Pococo Galaxy star projector is a simple and stylish model with lots of potential"

The projector can be purchased with a pink and blue ombré paint job, or in plain white. The white model is a touch more expensive, but perhaps it will appeal to a larger audience. The device only has three buttons: one to turn it on, one to start the rotation and one to set the timer. The operation couldn't be simpler.

The projections from this little projector are undoubtedly bright, sharp and vivid. The centre wheel at the top is easy enough to turn with one finger to bring the images into focus. There's enough 'movement' in the focus wheel for projections at a range of distances. The ideal distance is 2.5 metres (8.2 feet), with a 12 square metre (129 square foot) projection area. The image quality easily rivals that of the much more expensive Sega Homestar Flux, even though the LED projector isn't as powerful.

Switching between the discs is easy, and there's only one way they'll fit, so you can be sure the image is always projecting the right way around. They are a little on the small side, so it's a bit fiddly, but really no problem. Interestingly, we discovered that these little discs are the same size as – and thus also fit – the Orzorz star projector discs.

The rotation motor is either on or off, with no ability to adjust the speed like some models, where you can make it quicker or slower depending on your preference. It rotates fairly slowly, creating a calming effect, so we don't really see the need for having more than one speed. The motor is nearly silent. Some models we've reviewed give off a loud whirring noise, but with the Pococo you can only hear it if you have your ear pressed against the device, so it won't keep you awake, distract you from your conversation or interrupt your film-watching experience should you have the projector on at the same time, to add ambiance to a science-fiction film, for example.

There's a timer function that you can set for the projector to turn off after 15, 30 or 60 minutes. If you don't select one, the device will auto-power off after two hours. For us, this is a little short. If you wanted to project this alongside a long science-fiction film, for example, it wouldn't last the duration. We'd prefer four hours as a minimum.

Operation is very simple – just three buttons control the timer, rotation and power, and then the focus wheel to make your images sharp. There are no convoluted apps or Wi-Fi and Bluetooth connections needed to access the full functionality. Being rechargeable, you're not limited by the length of a power cord, so you can put the projector on otherwise inaccessible bits of furniture or shelves. If you're projecting onto the ceiling from close proximity you do get a harsh circular edge around the projection. The further you move away, the less harsh the contrast is between the projection and darkness, but the edges become a little blurry.

Nine different expansion packs of six discs are available for $69.99 (£54.95) per box, which is more than reasonable when compared to the Sega Toys Homestar Flux discs, which cost $20 ($15.70) per disc. We liken the experience of this galaxy star projector to having a space-themed poster on the wall that you can change every day and carry around to whichever wall or ceiling you choose.

We think the Pococo Galaxy Projector is a great, reasonably priced buy. It does what it's supposed to, projecting high-quality imagery onto any surface to immerse you in the wonders of the universe, maintaining a static picture or slowly rotating image. The fact that it's rechargeable is a plus compared to the much more expensive Sega Toys Homestar Flux, as it means you aren't limited to keeping it near a power source. The coloured design might not be for everyone, but it's still quite discrete, and a white option is available for an additional cost. The expansion packs are much cheaper, too, and the discs also work with certain other star projectors. Should you change to one of those in the future, you won't have to start your collection again.

The Pococo's batteries mean it can be placed anywhere and recharged later

FOR

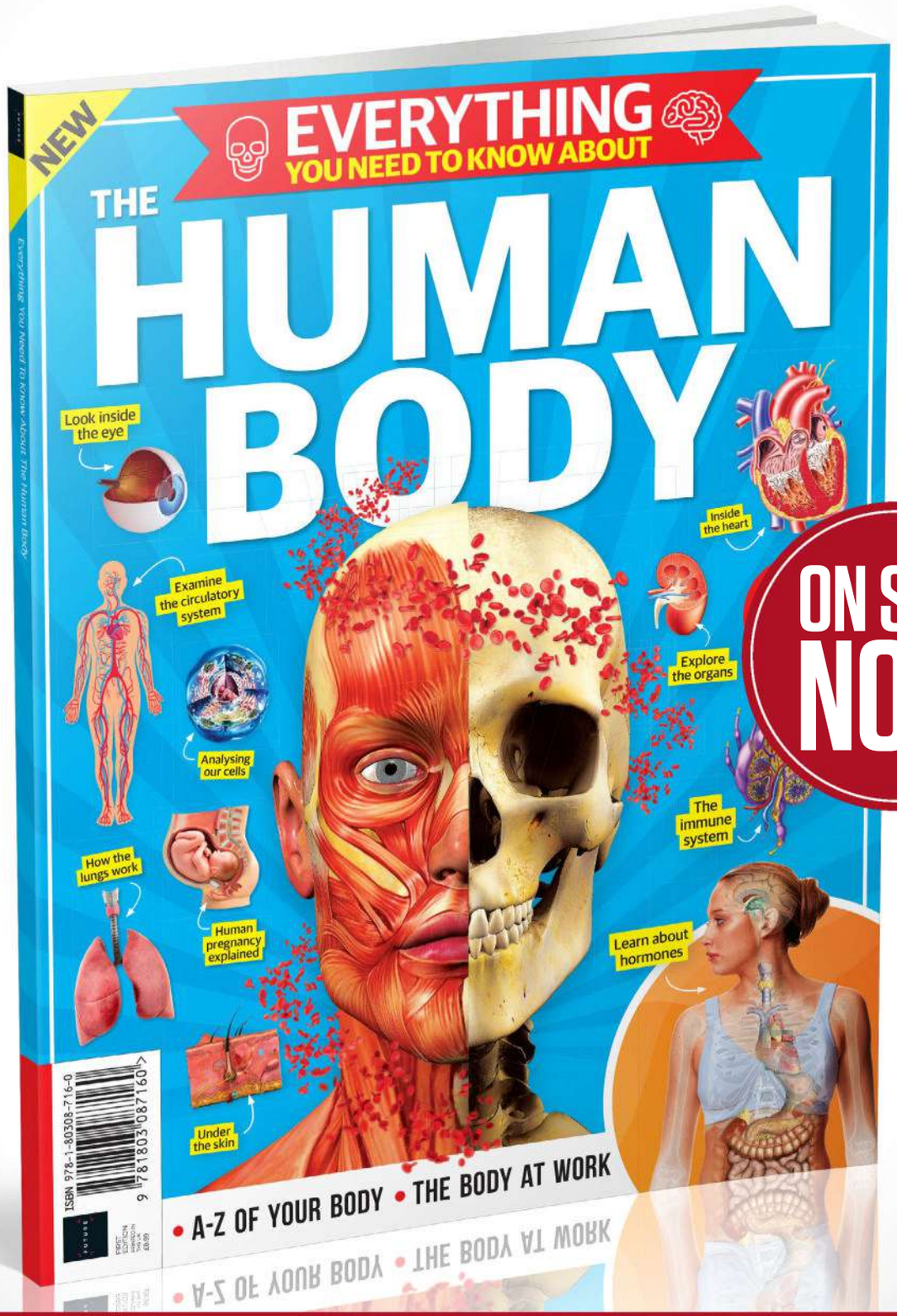
- Rechargeable battery or mains powered
- Realistic imagery
- Expansion packs available

AGAINST

- Strange marketing
- No remote or app control

TAKE A TOUR OF YOUR ANATOMY WITH OUR HEAD-TO-TOE GUIDE

How do our organs function? How do our wounds heal? Why do we dream? We answer these burning questions and more in Everything You Need to Know About the Human Body!



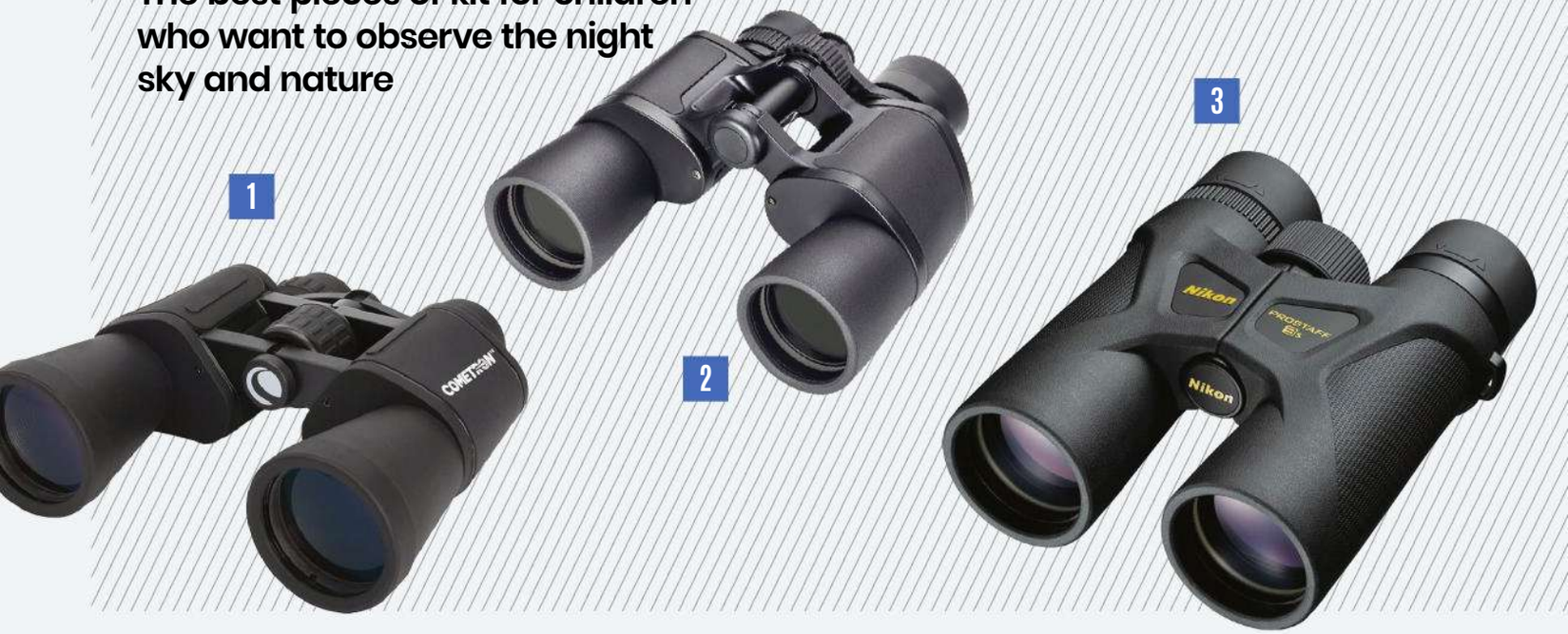
ON SALE NOW

FUTURE

Ordering is easy. Go online at:
magazinesdirect.com
Or get it from selected supermarkets & newsagents

IN THE SHOPS: BINOCULARS FOR YOUNG STARGAZERS

The best pieces of kit for children who want to observe the night sky and nature



Celestron Cometron 7x50

Cost: £59.00 / $56.90
From: Celestron

1 What most don't appreciate about children is that they can see a lot better in the dark than adults. That's because their pupils can dilate wider, which makes their night vision better. Should you give a child a binocular that's easier to carry and hold, but allows less light in? That's one option. Another is to go for a binocular like the Celestron Cometron that manages to be both reasonably lightweight and lets as much light in as possible. That way you're allowing them to see everything in the night sky they possibly could. With 7x magnification and a 50mm objective lens, the Celestron Cometron is ideally sized for stargazing. What's more, it boasts multi-coated optics that comprise a stargazing-centric Porro prism, though it does utilise step-down BK7 glass. It also has a large exit pupil, which guarantees maximum light during the night and at dawn and dusk. It's also easy to adjust to smaller faces.

Opticron Adventurer T WP 8x42

Cost: £79 / $129
From: Opticron

2 If you want a good binocular for astronomy and the night sky that is best suited to kids, those with an 8x magnification and a 42mm objective lens are perfect. A slight comedown from the 10x50 specification that's recommended for adults, 8x42 is the ideal match-up in terms of weight, magnification and light-gathering at night, and the Opticron Adventurer T WP 8x42 is an excellent value example. A Porro prism design using BAK-4 glass prisms with fully multi-coated lenses, it's water and dew-proof and comes dressed in protective rubber-like armour. In the box is a soft case, a neck strap and rubber objective lens covers. It also features long eye relief eyepieces so can easily be used by glasses wearers. Light, compact, waterproof and boasting great views of the night sky, the Opticron Adventurer T WP 8x42 makes for an ideal entry-level option for kids with a serious interest in astronomy, but is just as good during the day for wildlife.

Nikon Prostaff 3S 8x42

Cost: £149 / $139.95
From: Nikon

3 If you're looking for a good binocular that can be used by all the family and offers top-quality performance, look no further than this one from top photography and optics brand Nikon. A step-up purchase, this mid-range binocular is not only beginner-friendly, but well suited to use by kids. Covered in non-slip rubber for easy grip and shock resistance if dropped, the Nikon Prostaff 3S binocular is guaranteed to be both fog-free and even waterproof. Reasonably slim, compact and lightweight considering the size, it's easy to hold for long periods of stargazing, while images are sharp, clear and bright thanks to multilayer-coated lenses and high-reflectivity silver-alloy mirror coated prisms. A long eye relief design also means a clear field of view for glasses wearers. The specifications are ideal for stargazing, too, boasting the classic 8x magnification and a 42mm objective lens that's perfect for lightweight light-gathering.

"Perfect for zooming in on the Moon and star clusters like the Pleiades and Hyades"

Celestron SkyMaster 12x60

Cost: £83 / $104.95
From: Celestron

4 Though relatively large and heavy, the Celestron SkyMaster 12x60 binocular will be perfectly suited to any child who's outgrown a pair of small binoculars and wants to get a close-up of deep-sky objects without moving into telescope territory. It's perfect for zooming in on the Moon and star clusters like the Pleiades and Hyades. However, at 210 by 206 by 72 millimetres (8.25 by 8.1 by 2.8 inches) and weighing in at 1.1 kilograms, we recommend mounting the Celestron SkyMaster 12x60 on a tripod to make it easier to hold still. Built around a Porro prism design featuring BAK-4 prisms; boasting multi-coated optics for sharp, bright and highly detailed views and with an objective lens of 60mm to let as much light in as possible, the Celestron SkyMaster 12x60 has an ultra-firm rubber coating on its barrels that's easy to hold and helps protect it. Also included is a carry case and some lens caps.

National Geographic 6x21 child binocular by Bresser

Cost: £29.99 / $35.90
From: Bresser

5 Rugged, compact and designed to go anywhere, this is a classic 'my first binocular'. Created especially for young children and in a harsh polycarbonate housing, this roof prism binocular with BK7 glass comes with a small case and a wrist strap to make it harder to lose. That's important because they're pretty small, featuring only 6x magnification. That, together with just 21mm objective lenses, means it's useful only for looking for the Moon, lacking the light-gathering abilities of superior astronomy-specific binoculars. However, since kids tend to be shakier than adults, that small amount of magnification can help everything seem more stable than when using binoculars designed for adults. It also makes it easy to find things like the Moon. But don't mistake them for a throwaway novelty; inside you'll find surprisingly good optics and anti-reflective coatings that brighten the image.

Celestron Nature DX 8x32

Cost: £129.99 / $149.95
From: Celestron

6 Want to keep it small and light? Although 10x50 is the standard for astronomy binoculars meant for adults, that's a lot to hold. If a child is going to be using them as much by day as by night, consider investing in a smaller all-round binocular like the Nature DX 8x32. With 8x magnification and 32mm objective lenses, it's lightweight at 510 grams and the outer covering makes them easy to hold, as well as waterproof. It can probably take a few knocks, too. Inside are BAK-4 prisms with a phase coating to maximise contrast and sharpness, though just as importantly for astronomy it has multi-coated optics that maximise light transmission for brighter images in the dark. Unusually for such a small binocular, you also get a built-in tripod mount. Aimed at beginners and general use but with excellent optics and an outdoorsy construction, the Celestron Nature DX 8x32 will best suit older kids after something portable and versatile.

HEROES OF SPACE

EUGENE KRANZ

Failure wasn't an option when the lives of the Apollo 13 crew were at stake

Spaceflight doesn't come without risks. Kranz knows this more than most, for as he was overseeing the Apollo 13 mission, he witnessed a crippling explosion that put the crew in grave danger. It was 13 April 1970, and a live television broadcast from the craft had just ended. Running through some standard checks, Jack Swigert turned on the hydrogen and oxygen tank stirring fans that were located in the Service Module, and disaster struck. An electrical fault caused one of the oxygen tanks to explode, and Swigert reported a venting of gas. It was oxygen and it was depleting fast, putting the onus on Kranz to make some fast and hard decisions. He was the flight director assigned to all of NASA's odd-numbered missions. But despite his young age of just 36, his cool and calm demeanour was so admirable that it saw him recognised in a Space Foundation survey as the second most popular space hero after astronaut Neil Armstrong.

Kranz had two choices: cut the lunar landing loose, fire the engine and turn the craft around on a direct course back to Earth, or swing the craft around the far side of the Moon to slingshot it back towards Earth. He opted for the latter, even though it would take longer to return the crew. Flight controllers objected, pointing to the rapid loss of oxygen, but Kranz was thinking very clearly, and he was sure he was right.

Ensuring that his Mission Control 'white team' carried out their duties with the greatest of focus, he urged against guesswork and handled the pressure well. Constraints for the consumption of spacecraft consumables – that is, oxygen, electricity and water – were set, and Kranz's team controlled the course-correction burns and power-up procedures. What followed was an extremely tense period, but on 17 April 1970, Apollo 13 splashed down in the Pacific Ocean, the crew members alive and well. It was an undoubted triumph and the highlight of Kranz's career. Yet it was perhaps no surprise.

Born in Toledo, Ohio, on 17 August 1933, he had proven to be very successful, graduating from Parks College in St Louis, Missouri, with a degree in aeronautical engineering in 1954 and going on to enjoy a four-year career in the Air Force before joining NASA. He'd worked on the first and third Mercury missions in 1961 and 1962 respectively and was promoted to assistant flight director for the fourth. Kranz was flight director for Apollo 11 when the Lunar Module landed on the Moon in 1969.

The problems with Apollo 13 didn't deter him, though. After receiving the Presidential Medal of Freedom, he remained a flight director until 1972, finishing with Apollo 17. He became deputy director of NASA Mission Operations in 1974 and director in 1983. Kranz retired from NASA in 1994, a year after the Hubble repair flight.

ALL ABOUT SPACE ISSUE 146

ON SALE 10 AUG

© Getty / Alamy

ALL ABOUT SPACE

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Gemma Lavender**
gemma.lavender@futurenet.com
Art Editor **Jonathan Wells**
Production Editor **Nikole Robinson**
Senior Art Editor **Duncan Crook**

Contributors
Sophie Allen, Stuart Atkinson, Josh Barker, Abigail Beall, Mike Brown, Lee Cavendish, Charles Q. Choi, Paul Cockburn, David Crookes, Curtis Fermor-Dunman, Bernard Harris Junior, Andrew Jones, Ken Kremer, Sharmila Kuthunur, Robert Lea, Tereza Pultarova, James Romero, Rebecca Sohn, Linda Spilker, Paul Sutter, Carlos Tamarit, Neil deGrasse Tyson, Isobel Whitcomb

Cover images
Getty; NASA; Tobias Roetsch

Photography
Alamy; ESA; ESO; NASA; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Advertising Sales Director **Lara Jaggon**
lara.jaggon@futurenet.com
07515 961 911
Account Manager **Hayley Brailey-Woolfson**
hayley.baileywoolfson@futurenet.com
01643 678 054

International Licensing and Syndication
All About Space is available for licensing and syndication. To find out more contact us at **licensing@futurenet.com** or view our available content at **www.futurecontenthub.com**.
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Enquiries **help@magazinesdirect.com**
UK orderline & enquiries **0330 333 1113**
Overseas orderline & enquiries **+44 (0)330 333 1113**
Online orders & enquiries **www.magazinesdirect.com**
Group Marketing Director, Magazines & Memberships **Sharon Todd**
Disruption remains within UK and international delivery networks. Please allow up to seven days before contacting us about a late delivery at **help@magazinesdirect.com**

Circulation
Head of Newstrade **Ben Oakden**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Senior Advertising Production Manager **Jo Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Nick Williams**

Management
SVP Lifestyle, Knowledge and News **Sophie Wybrew-Bond**
Managing Director **Chris Kerwin**
Editor-in-Chief **Timothy Williamson**
Head of Art & Design **Greg Whitaker**

Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU **www.marketforce.co.uk**

ISSN 2050-0548

All contents © 2023 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

Widely Recycled

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards.

FUTURE
Connectors. Creators. Experience Makers.

Future PLC is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief Executive Officer **Jon Steinberg**
Non-executive Chairman **Richard Huntingford**
Chief Financial Officer **Penny Ladkin-Brand**

Tel +44 (0)1225 442 244

ipso Regulated

Advertisement

Car, home and travel insurance plus broadband, breakdown cover and more. Get more info or compare quotes, for over 40 products, at go.compare

Sky-Watcher®

Be amazed.

POPULAR BEGINNER & INTERMEDIATE TELESCOPES

"This telescope made observing the night sky enjoyable....great views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE GROUP TEST WINNER

ASTROLUX
76mm f/9.2 REFLECTOR

Sky at Night MAGAZINE GROUP TEST WINNER

MERCURY-705 (AZ3)
70mm f7.1 REFRACTOR

SRP £159

CAPRICORN-70 (EQ1)
70mm f/12.8 REFRACTOR

"Meets all expectations and is the perfect starter scope"
BBC SKY AT NIGHT MAGAZINE

SRP £139

SRP £109

EXPLORER-130 (EQ2)
130mm f/6.9 REFLECTOR

SRP £199

SKYHAWK-1145P (EQ1)
114mm f/5 PARABOLIC REFLECTOR

SRP £179

EXPLORER-130P (AZ-GO2)
130mm (5.1") f/5 Wi-Fi GO-TO Parabolic Reflector

SRP £339

SKYHAWK-1145P (AZ-GO2)
114mm (4.5") f/4.4 Wi-Fi GO-TO Parabolic Reflector

SRP £399

SKYMAX-127 (AZ-GO2)
127mm (5") f/11.8 Wi-Fi GO-TO Maksutov-Cassegrain

SRP £529

SRP £649

SKYMAX-127 (AZ-GTI)
127mm (5") f/11.8 Wi-Fi GO-TO Maksutov-Cassegrain

Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 152 January 2018

STAR DISCOVERY P150I 150mm (6")
f/5 Wi-Fi GO-TO Parabolic Reflector

SRP £599

EXPLORER-150PL (EQ3-2)
150mm f8 PARABOLIC REFLECTOR

SRP £399

Sky at Night MAGAZINE GROUP TEST WINNER

EXPLORER-200P (EQ5)
200mm f/5 PARABOLIC REFLECTOR

SRP £749

SKYLINER-200P CLASSIC
203mm f/5.9 PARABOLIC DOBSONIAN

Sky at Night MAGAZINE HIGHLY COMMENDED 93%

SRP £449

SKYLINER-250P CLASSIC
254mm f/4.7 PARABOLIC DOBSONIAN

SRP £659

HERITAGE-150P FLEXTUBE™ (VIRTUOSO GTI)
150mm f/5 Wi-Fi GO-TO PARABOLIC DOBSONIAN

SRP £449

SKYMAX-127 (VIRTUOSO GTI)
127mm f/11.8 Wi-Fi GO-TO MAKSUTOV-CASSEGRAIN

SRP £599

HERITAGE-130P FLEXTUBE™
130mm f/5 PARABOLIC DOBSONIAN

SRP £219

HERITAGE-150P FLEXTUBE™
150mm f/5 PARABOLIC DOBSONIAN

SRP £289

STAR ADVENTURER MINI PRO PACK
STAR TRACKER

Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 143 April 2017

SRP £269

Wi-Fi

DSLR & Tripod not included

9021

9000

Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk